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15 July 1980

USSR Report

ENERGY

(FOUO 11/80)

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JPRS L/9195

15 July 1980

USSR REPORT

ENERGY

(FOUO 11/80)

CONTENTS

ELECTRIC POWER

UDC 621.31.002.51

CHARACTERISTICS OF KOSTROMSKAYA STATE REGIONAL ELECTRIC POWER STATION

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 2, Feb 80 pp 2-5

[Article by Engineers G. I. Pleskov, S. L. Nuger, V. V. Mayboroda, N. A. Fomin and Yu. V. Gorelov]

[Text] In expanding the Kostromskaya State Regional Electric Power Station plans called for installing two power units each with a power of 1,200 MW. However, subsequently it was decided to install only one power unit and finalize the construction of the electric power station (Fig. 1).

In the power unit there is a suspended single-housing gas-mazut boiler of the TGMP-1202 (TKZ) type, operating on the supercharging principle, and a K-1200-24-240-3 turbine (LMZ) with a TVV-1200-2UZ generator (LEO "Elektrosila")(Table 1).

The single-shaft L-1200-240-3 (LMZ) turbine is characterized by increased thermal economy, especially under partial loads. The flowsheet for the power unit provides for the possibility of turbine operation in different regimes. With cutting-off of the high-pressure heater its power can be brought to the level of 1,400 MW.

The thermal economy of the 1,200-MW power unit is 0.6% greater than for a power unit of 800 KW. This makes it possible to reduce the specific fuel expenditure (scaled to conventional fuel) by 0.2 g/(KWhr), which corresponds to a savings of 145,000 tons annually.

The carrying out of scientific research work in the field of aerodynamics and strength of materials, the checking-out of units in the course of stand and field tests made it possible to create a prototype of a turbine with a power up to 2,000 MW.

Much attention was devoted to the working-out of the start-up and technological schemes ensuring a high economy of power unit operation. For example, the installation in the 300-MW power units of the existing part of wide-range 4/1.3 MPa ROU with steam takeoff from industrial superheating systems (lines) (80-90 tons/hour in the range of power unit load ranges 100-50%) ensures a mobile and economical start-up with coverage of the loads in hot

Table 1

Index	Boiler	Turbine
Type of fuel	Mazut, gas	--
Nominal power, MW	--	1200
Steam productivity, tons/hour	3950	--
Steam expenditure, tons/hour:		
at inlet to turbine	--	3927
at inlet to intermediate superheater	3151	--
Steam pressure, MPa:		
high pressure	25.5	24
cold intermediate superheating	4	4.08
hot intermediate superheating	3.75	3.66
Steam temperature, °C:		
high pressure	545	540
cold intermediate superheating	292	294
hot intermediate superheating	545	540
Temperature of feed water, °C	278	278
Computed temperature of cooling water, °C	--	12
Expenditure of cooling water in condenser. 1000's m^3/hour	--	108
Expenditure of mazut, tons/hour	273	--
Efficiency of boiler (gross), operating on mazut, %	94.7	--
Number of cylinders:		
high pressure	--	1
intermediate pressure	--	1
low pressure	--	3
Specific expenditure of heat (gross) KJ/ KW·hour)	--	7673.4

and cold steam and also an increase in the economy of electric power station operation and the possibility of dismantling the start-up boiler unit.

In the drive turbines of the feed pumps and blowers the steam ejectors have been replaced by water-jet units. The systems for discharge of condensate and packings have been simplified. For the blower turbines there is an integrated system for oil supply with installation of a single oil tank; variants of layouts of blower condensation turbines without and with basements were worked out.

The installation of low-head blowers, intended for the shot cleaning of the boiler, in the main building made it possible to dispense with the construction of a separately constructed compressor unit and to unload the supports for the feed and drain lines; the suction system for the blowers was designed in the form of a lightened external box. Such a solution made possible a sharp reduction in aerodynamic resistance at the suction point and the use of blowers similar to those employed for a standard 800-MW power unit. The introduction of rational schemes for the transfer of thrust and improvement in the layout of the principal lines made it possible to reduce the expenditure of metal in fabricating the lines for the 1,200-MW power unit in comparison with an 800-MW power unit (Table 2).

Table 2

Main lines	1,200-MW power unit (Metal expenditure)		800-MW power unit (Metal expenditure)		Reduction in metal used in lines, %
	total, tons	specific, kg/KW	total, tons	specific, kg/KW	
High-pressure lines, including fittings and supports	1810	1.51	2120	2.55	39.3
Low-pressure lines	2030	1.69	1850	2.31	26.8
Boiler gas-air system	1795	1.5	1750	2.19	31.5

In developing the layout of the power unit in a 72-m space there was optimization of the positioning of equipment, layout of the lines and the gas-air system. In this stage there was finally finalization of the design solutions for the general station and turbine lines. Due to the installation of feed pumps along the turbine it was possible to have a compact arrangement of equipment in the machine room, a reduction in the length of the lines and an increase in the dimensions of the repair areas. (The control panel was placed at the 3.80-m level in the deaerator section.)

The carrying out of complex computations for autocompensation of high-pressure station lines, together with the lines situated within the boiler and turbine, as well as optimization of their layout, made it possible to reduce the specific expenditure of metal on their fabrication in comparison with an 800-MW power unit (Table 2).

In order to increase the level of mechanization of repair and installation work and in order to shorten the time required for carrying out this work, in planning the main building of the third stage of the Kostromskaya State Regional Electric Power Station, in addition to the traditional mechanization facilities, in the machine room provision was made for the installation of a gantry load crane with a lifting capacity of 5 tons with a span of 24 m between the supports at the operations level for servicing the turbogenerator and a considerable part of the auxiliary equipment. A gantry load crane with a lifting capacity of 3 tons was installed over the feed turbopumps, whereas in the repair-installation area there is a jib crane with a 15-m boom.

For the mechanization of work in the boiler section use was made of special jib cranes with a lifting capacity of 10 tons each. Due to the limited height of lifting (36 m) of these cranes, for the organization of vertical transport work a loading platform was arranged for at the level 30.50 m. Two hoists, each with a lifting capacity of 1 ton, of the "Gnezno" type, and two elevators, each with a lifting capacity of 1 ton, were installed in the vicinity of the frame supports of the boiler section.

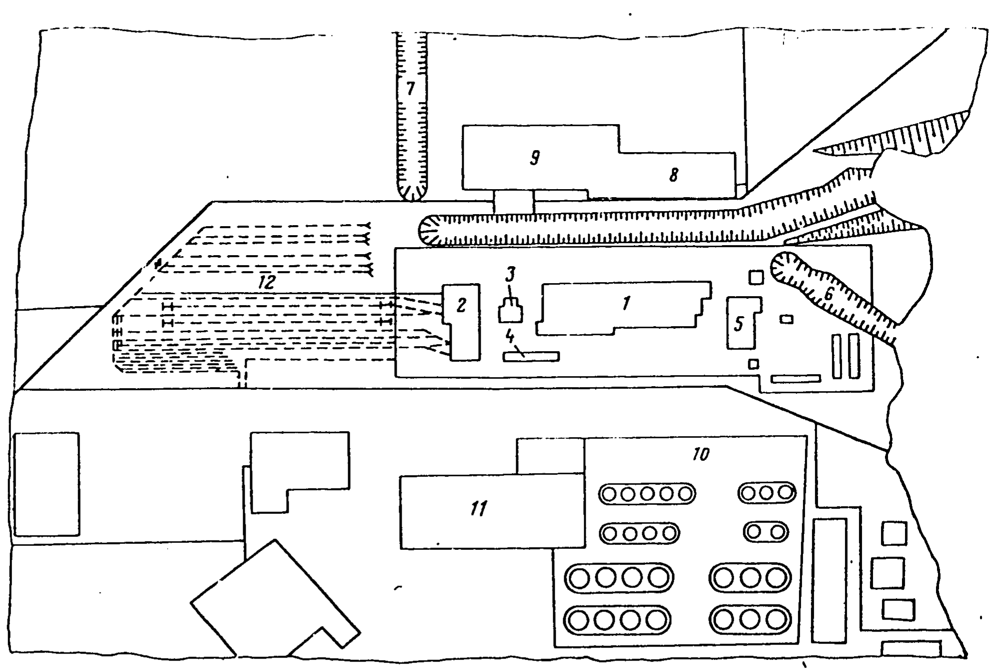

Fig. 1. General plan of State Regional Electric Power Station with a power of 3,600 MW. 1) main building of first and second stages; 2) main building of third stage; 3) laboratory-residential building; 4) chemical water purification; 5) OVK; 6) inlet canal; 7) discharge canal; 8, 9) 220- and 500-KV ORU; 10) mazut farm; 11) purification structures; 12) construction base

The system for control of the 1,200-MW power unit was constructed using the functional-group principle. The operation of this power unit was controlled by an "ASVT-Kompleks" control system intended for the registry of the state of the equipment during a "prealarm" period and at the time of an alarm, the triggering of protective units and coordination of operation of functional groups.

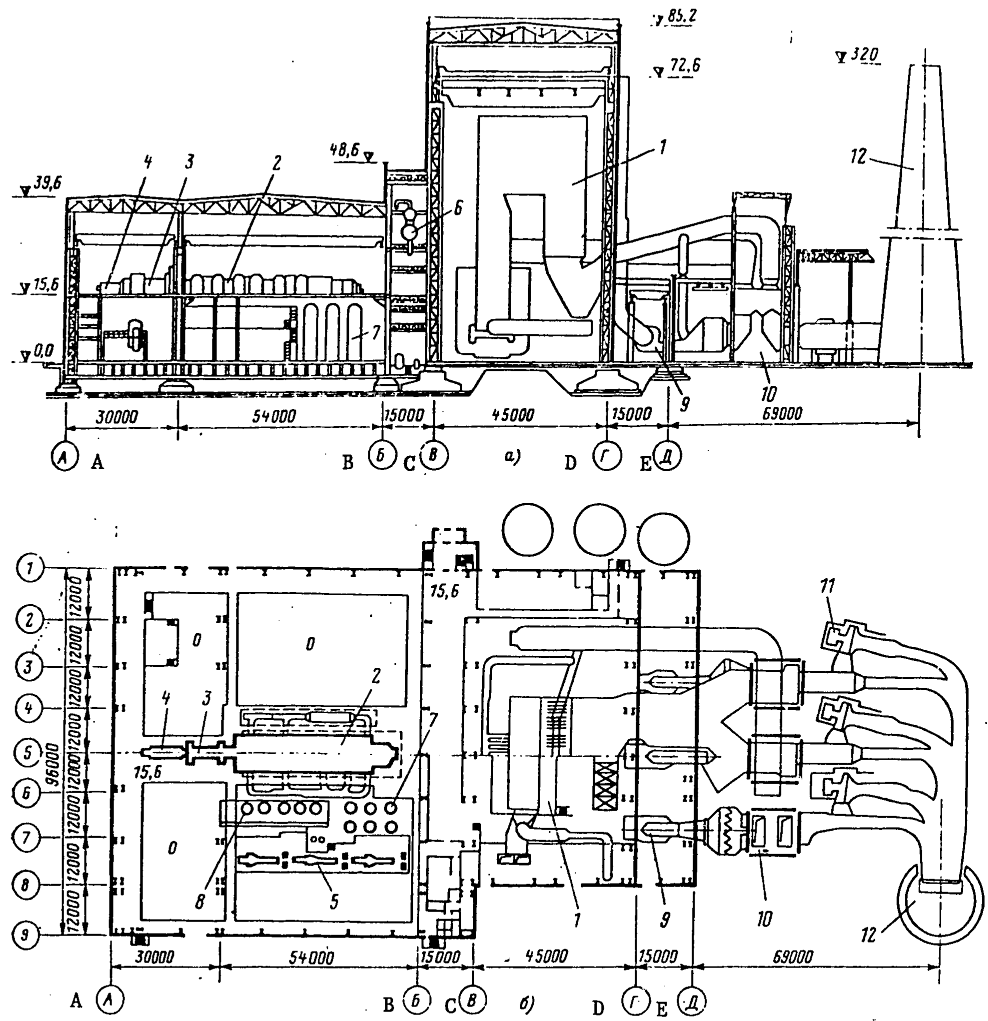

Fig. 2. Diagram of arrangement of main equipment in main building. a) cross section; b) layout. 1) single-pass single-housing boiler; 2) turbine; 3) generator; 4) exciter; 5) feed turbopump; 6) deaerator; 7) high-pressure heaters; 8) low-pressure heaters; 9) blower; 10) regenerative rotating air heater; 11) smoke exhaust; 12) stack

In connection with the extensive use of such instrumentation for functional-group control and new systems for automatic control of thermal heating there was a marked increase in the expenditure of control cable. In order to reduce the work input and reduce the time required for the construction of the electric power station, in laying out the branching cable network extensive use was made of factory-produced metal boxes, and especially of the KP type.

In order to improve working conditions for operations personnel after putting the 1,200-MW power unit into operation the central control panel is being transferred from the main building to the engineering-residential building situated between the main buildings of the second and third stages of the State Regional Electric Power Station.

The 1,200-MW power unit includes a special six-phase turbogenerator of the TVV-1200-ZUZ (LEO "Elektrosila") type. The windings of the generator rotor are cooled by hydrogen and the stator by distilled water.

In the unit with the turbogenerator there is a group of single-phase ORTs-533000/500-74U1 transformers with an in-phase power of 533,000 KVA with a nominal voltage of the low-voltage winding $24\text{-}24/\sqrt{3}$ KV. The transformer has an oil-water cooling system. The total power of the turbogenerator in a nominal regime is 133,000 KVA, in the maximum admissible regime -- 1,468,000 KVA with $\cos \varphi = 0.9$ and 1,412,000 KVA with $\cos \varphi = 0.85$.

Tests of the turbogenerator revealed that it has considerable heating reserves under a nominal load, which is a guarantee of reliable operation of the electric part of the power unit with a power 1,200 MW under prolonged operating conditions.

Due to the use of a turboblower for the boiler the power of the working transformer (for internal requirements) was set at 40 MVA (taking into account the installation of three reserve exhaust fans); the power of the reserve transformer is 63 MVA.

The use of such a transformer with such a power for internal requirements made it possible to reduce the level of short-circuiting currents across the internal-requirement busbars, thereby ensuring reliable operation of the 6-KV electrical equipment in the basic regimes. Standard-produced switching boxes with electromagnetic arc extinction (K-XXV) were used in the 6-KV internal-requirements distribution apparatus.

Since the short-circuiting currents across the 500-KV ORU busbars exceed 30 KA, after the introduction of the 1,200-MW power unit provision is made for the installation of VNV-500 switches with a nominal cutoff current of 40 KA at the electric power station.

In connection with the introduction of the 1,200-MW power unit at the Kostromskaya State Regional Electric Power Station the 500-KV ORU is being constructed in a so-called "1 1/2" scheme with sectionalization of one system of busbars for excluding the simultaneous loss of electric power received from the 1,200-MW power unit and the paired 600-MW power units of the second stage of the State Regional Electric Power Station.

The 1,200-MW power unit has a complete set of relay protection devices. The generator protection devices are duplicated for each stator winding. Provision is made for the installation of "remote reserving" protection devices and an automatic anti-accident system with provision for a system for the automatic feeding of control signals and a TA-100 teleautomatic complex.

The dimensions and load of the unique basic equipment predetermined the creation of fundamentally new layout and design solutions for the main building (Fig. 2). In particular, new design solutions were worked out for the frame and the main foundations of the main building.

In the course of planning a detailed analysis was made of experience in operation of earlier constructed foundations of turboplants and stacks. This made it possible to draw up a plan for a prefabricated monolithic foundation for the turbine, situated in the main building, with good technical-economic indices satisfying the rigorous requirements of power plant equipment specialists.

A fundamentally new design solution was also adopted for the foundation of the building of the boiler section, in whose frame a boiler with a mass of 20,000 tons was suspended across ridged beams.

The introduction of rigorous restrictions on deformations of the frame for the boiler section (half the deformation allowed for ordinary industrial buildings), introduced by the fabricating plant, required the development of a new building frame design with a well-developed system of construction members.

The need for precluding the undesirable influence of settling of the building frame due to flexure of the turbine foundation dictated the carrying out, for the first time in the practice of power construction, of changing of the tracks under the crane in the machine room over the turbine at level A_1 to the form of a truss structure with a span of 48 m under the crane.

For the purpose of reducing the expenditure of steel and work expenditures the most loaded frame elements of the main building were made of 16G2AF highly durable steel; joining of the columns was by fitted ends. In the designing of bases of such columns the designers took into account the possibility of assembly without screws; the construction of the roof panels for the main building can be accomplished by installation as units.

It was provided that the enclosing structure of the main building for the most part be made of shaped sheet steel.

The use of prefabricated silicate-polymer elements for fabricating gas lines with a gas diversion box will ensure their high reliability and longevity, as well as a reduction of the expenditure of sheet steel by 1,500 tons.

It should be noted that the introduction of the new technical solutions in the construction of the third stage of the State Regional Electric Power Station will make it possible to reduce by more than half the specific expenditures of work and reduce them to 1.426 man-days/KW.

Due to the reduction of expenditures of materials and metals, in the last analysis there is a decrease in the time required for construction of the electric power station and capital expenditures.

5303
CSO: 1822

ELECTRIC POWER

UDC 624.13;624.152.2

EARTH WORK ON CONSTRUCTION OF KOSTROMSKAYA ELECTRIC POWER STATION

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 2, Feb 80 pp 22-26

[Unsigned article]

[Text] The carrying out of earthwork in constructing the principal parts of the third stage of the Kostromskaya State Regional Electric Power Station had a number of distinguishing characteristics. In particular, the earthwork on the the hydraulic structures and discharge canals was carried out earlier than the work on the main building; the system for deep lowering of the ground water level when working the excavations near the discharge canals provided for in the plan was not implemented. Such a decision was made on the basis of computations made in the computations section of the State Regional Electric Power Station. The results indicated that the alternative use of a system involving use of a unit pumping station for reducing the ground water level of the second head horizon would ensure a decrease in the water head in the excavation region near the discharge canals.

The working of the excavation was initiated in the first quarter of 1976 and was ended in the second quarter of 1977. The earthwork was carried out by the traditional method: in two levels with prior digging of the drainage ditches for intercepting surface water. The reinforcement of the slopes was accomplished by application of a layer of rubble with a thickness up to 300 mm and with the height up to 3 m from the bottom of the excavation. In order to ensure the possibility of simultaneous laying out of two discharge canals the width of the excavation was set at 10 m (along the bottom). After preparing the excavation base concrete work was immediately done for the reinforced concrete sides of the canal, which made it possible to ensure movement of transport vehicles along the bottom.

In examining the experience in carrying out earthwork, we should especially note the working of the excavation near the open discharge canal. A sector of the canal with a length of 300 m passes through a territory in which there are electric transmission lines with voltages of 500 and 220 KV. The volume of the ground to be worked in this sector amcunted to 18,820 m^3.

The planners had proposed the working of ground in this sector with two E-10011 excavators with the power in the transmission lines cut off (Fig. 1).

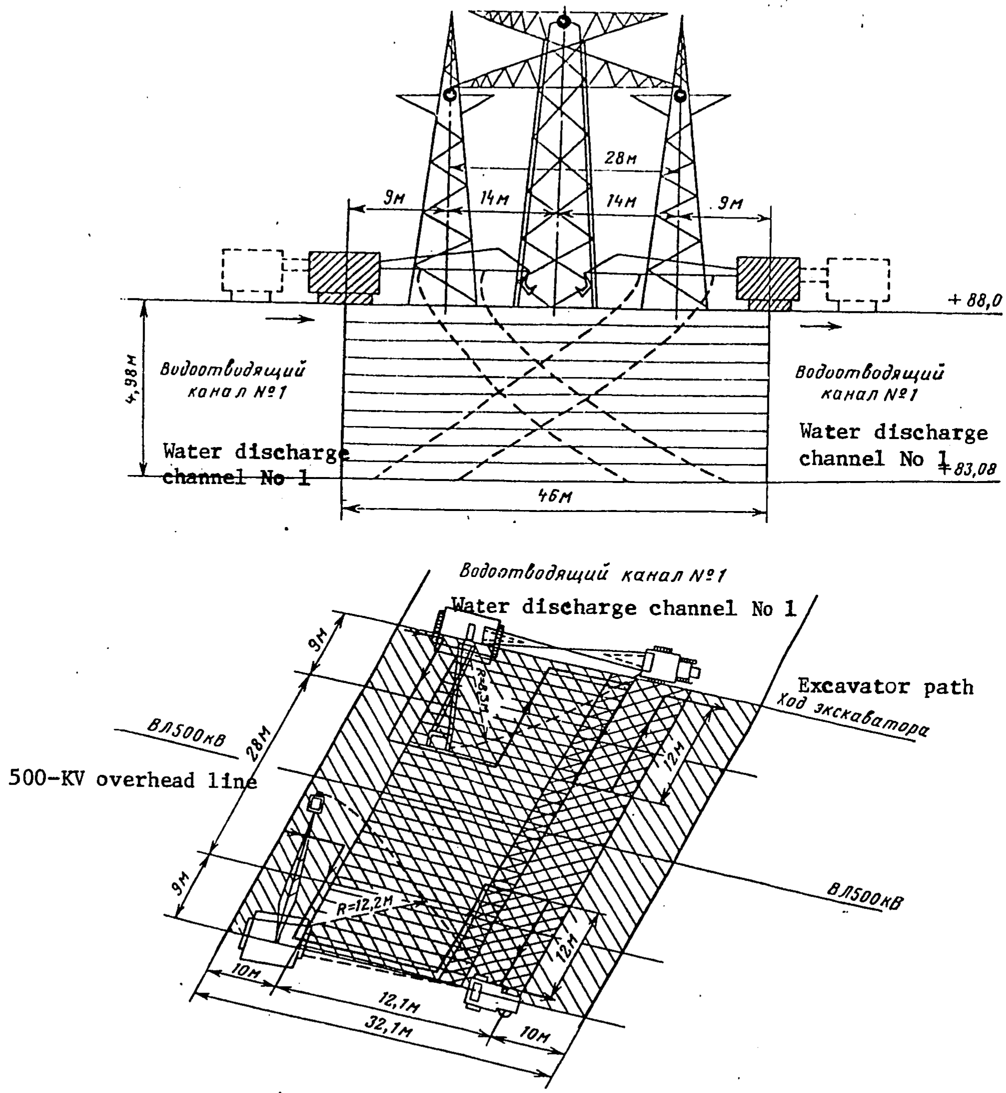

Fig. 1. Diagram of working of ground in canal No 1 with cutoff of 500-KV overhead line.

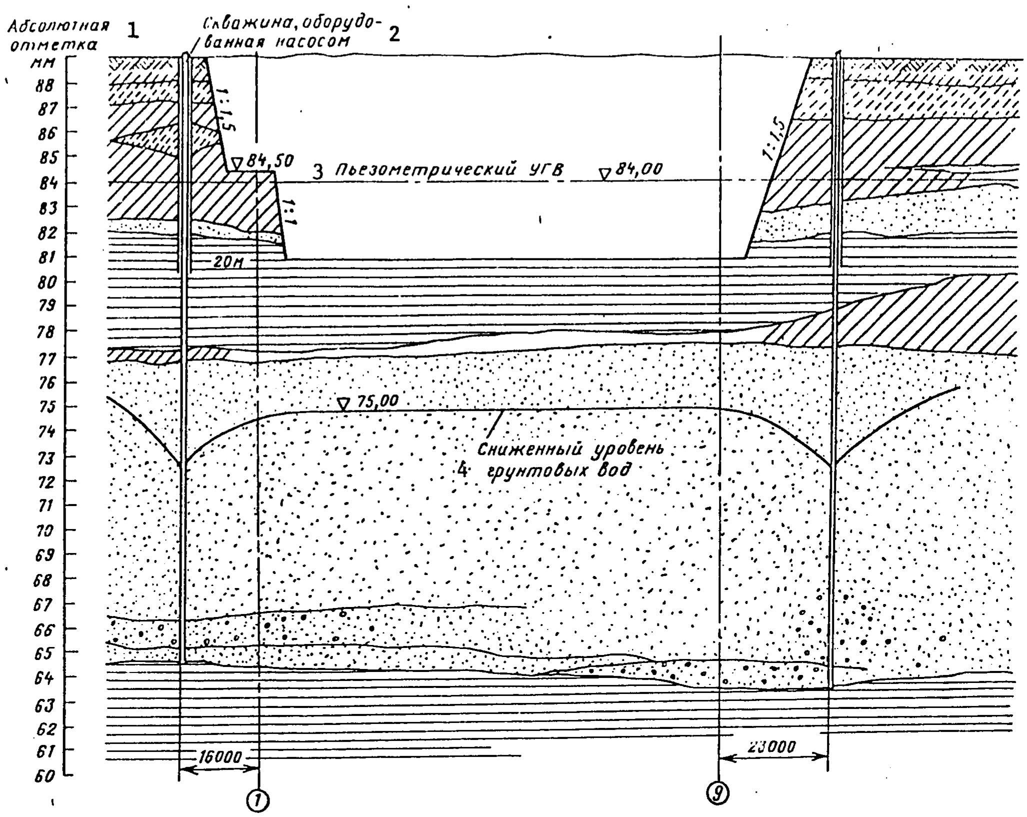

Fig. 2. Geological section of site of main building.

KEY:

1. Absolute reading
2. Borehole with pump
3. Piezometric ground water level
4. Reduced ground water level

The builders, after examining several variants of implementation of the earthwork, carried out the working of the ground without cutoff of the electric power lines. When carrying out the work use was made of six D-357-P scrapers with a MOAZ-546/P tractor. The scoop capacity was 8 m^3; engine power was 177.6 KW. Such a decision made it possible for builders to carry out the entire complex of work in the neighborhood of the 500/220 KV overhead line in the course of 15 days. The finishing of the excavation slopes was with an E-10011 excavator outfitted with a straight

Table 1

Balance of Earthwork Carried Out in Constructing Parts of 1,200-MW Power Unit

Part	Ground volume, 1000's m^3	Equipment	Number of machines	Number of trucks per shift	Time required to do work, months
Main Building	132.5	Excavator E-10011	4	8/6	12
Stack with Gas Outlets	16.8	Same	2	6/4	2
500/220-KV ORU	46.4	Same	2	6/4	18
Feed canal	144.8	Same	2	6/4	22
Unit pump station	182.9	Same	4	6/6	18
Pressure circulation line	5.7	Same	1	4/2	1
Reinforced concrete discharge canals	71.3	Same	2	6/4	6
Open discharge canal	173.9	Scraper D-357-P	6		
		Excavator E-10011	2	8/6	24
Chemical water purification	26.4	Same	2	4/6	10
Administrative-residential building	19.4	Same	1	2/2	4

1 The number of machines operating in the second shift is given in the denominator.

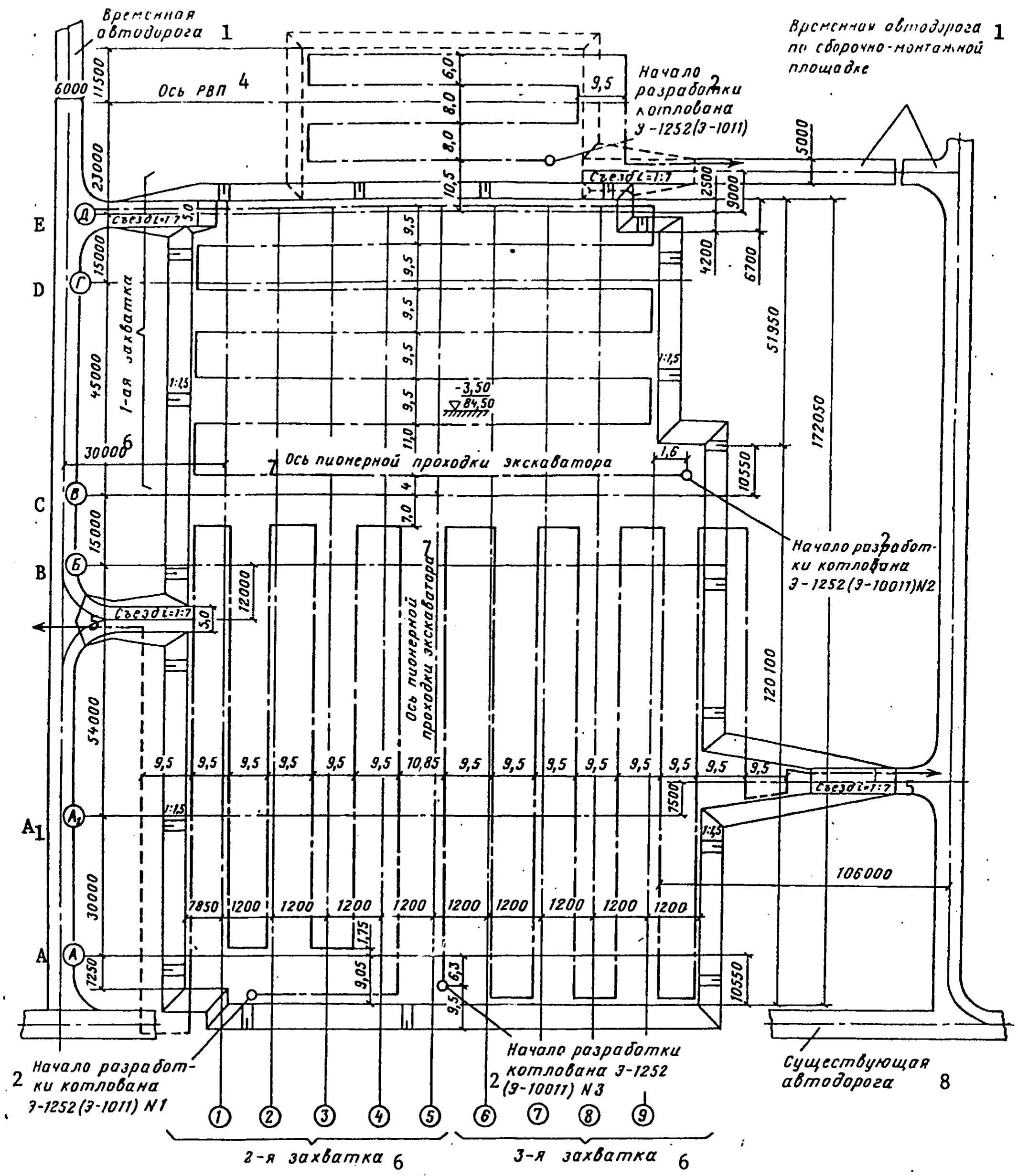

Fig. 3. Working of first horizon of excavation for main building. (Annotations on next page.)

KEY TO FIG. 3.

1. Temporary road
2. Beginning of working of excavation
3. Temporary road for assembly-installation work
4. Axis of RVP [expansion unknown]
5. Turn-arounds
6. 1st, 2d, 3d zones
7. Axis of initial pass of excavator
8. Existing road

---

shovel. The ground was removed by the scrapers to a distance of 1,200 m.

A peculiarity of carrying out earthwork in constructing the main building of the 1,200-MW power unit was the preliminary completion of the system for lowering the ground water level. The decrease in the level of the head horizon was tied into the submorainal sands (Fig. 2) to the level 75.00 m. According to measurement data, the volume of water pumped from 12 boreholes with a depth of 26 m for reducing the ground water level was 460 m^3/hour. The borehole filters of the slotted type had a diameter of 273 m.

A piezometric network was created for observing the reduction in ground water level. It consisted of five deep piezometers (outside and inside the boreholes), deployed at the borehole sites. The volume of extracted water was measured by a hydrometric apparatus. For its installation in the final head-free segment of the discharge pipe there was a cut "window" measuring 50 x 10 cm. In order to ensure the continuous operation of the APN-10 pumps with a discharge of 40 m^3/hour, installed in the system of boreholes for reducing the ground water level, the scheme for their electric supply was duplicated.

The system for reducing the ground water level was set up before beginning the working of the ground in the excavation and was activated only after completion of working of the first-horizon ground. After test pumping of the water from the borehole it was analyzed for its content of suspended matter. [The analysis was made by the operations service of the State Regional Electric Power Station.] Its results confirmed the computed data on absence of erosion of the submorainal sands.

After construction of the foundations for the main building, when the mass of laid-down materials and construction components became equal to the mass of ground removed from the excavation, the system of boreholes for reducing the ground water level was shut down and the boreholes were plugged by means of pumping in a cement-sand solution.

The excavation was worked in two levels: first -- from the leveled surface to the reading 2.00 m; second -- to the planned level 5.00 m. Slant filters were provided for intercepting the ground water of the head horizon and there was a water-diversion ditch with wells to receive the water. GNOM-16 and GNOM-40 pumps were used for pumping water from the wells.

Prior to laying of the concrete base, taking into account the importance of retaining an unimpaired structure of the ground in the neighborhood of the foundation of the turboplant, the ground with an impaired structure was removed manually. The working of the ground in the neighborhood of the machine room was accomplished using four E-10011 excavators (with a scoop capacity 1 m^3) with its loading into KrAZ-256 dump trucks each with a carrying capacity of 12 tons. The slopes of the excavation were leveled with E-10011 excavators. The slopes were finished with broken stone and rubble in a layer up to 300 mm to a height of 3.5 m from the bottom of the excavation (Fig. 3).

The deepest part of the excavation under the turbine foundation was worked in three levels. The working of the last, third level (reading 0.5-1.5 m) was with S-100 bulldozers; after reaching the planned reading the bottom of the excavation was immediately protected by a layer of M200 concrete with a thickness 100-250 mm.

In working the ground in the neighborhood of the boiler section the plan provided for the retention of ground of unimpaired structure at the center of the boiler section to the reading 2.00 m for the purpose of subsequent placement of a KB-160 tower crane in this sector for carrying out work on the concreting of the foundations under the frame of the boiler section.

The earthwork for construction of the 1200-MW power unit was carried out by a specialized section of the Tsentroenergospetsmekhanizatsiya Administration of the Tsentroenergostroy Trust. Prior to the beginning of working of the excavation under the main building approach roads were laid down for use in transporting the ground. The total volume of removed ground beneath the main building was 132,500 m^3 (see table).

The work was done by integrated teams having excavators, bulldozers and dump trucks at their disposal. The use of KrAZ-256 dump trucks, which in comparison with dump trucks of other types have the best passability, made it possible to dispense with temporary roadways in the excavation and in the ground dump (except for the spring period).

The considerable time required for working the ground in the excavation for the 1,200-MW power unit is attributable to the frequent diversion of earthmoving equipment and trucks to other construction sites of the Tsentroenergostroy Trust and the lack of technical specifications for the work to be done.

5303
CSO: 1822

ELECTRIC POWER

UDC 621.221.3

PROBLEMS IN CREATING HEAT ACCUMULATORS FOR ATOMIC ELECTRIC POWER STATIONS

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 2, Feb 80 pp 33-36

[Article by Doctor of Technical Sciences A. P. Kirillov, Candidates of Technical Sciences N. V. Pautin, M. Ye. Voronkov and Yu. B. Nikolayev, Engineer M. L. Okhlopkov, Candidate of Technical Sciences V. M. Chakhovskiy, Engineer G. S. Chegasov]

[Text] The problem of improving the "maneuverable" characteristics of power plants continues to remain timely. It is particularly expedient to increase their maneuverability in connection with the increase in the unit power of power units at thermal and atomic electric power stations and the increase in the fraction of production of thermal and electric power at atomic electric power stations. Therefore, the need arises for their improvement, for example, by the accumulation of energy during the time of a decrease in the load in the power system and its delivery during the period of a peak load. At the present time the most widely used method for the accumulation and delivery of peak electric power is the creation of a hydroaccumulation electric power station (HAEPS). However, the broad use of HAEPS is being held back by a number of factors: difficulty in selecting sites suitable for their construction, the high level of specific capital investments (160-200 rubles/KW), the necessity for appropriating considerable areas, etc.

In a number of countries investigations are being made of the possibility of using heat accumulators (HA) in the systems of atomic electric power stations for ensuring the stability of the operating regime of reactor equipment when it operates with a variable electric power [1-4]. Roots steam-water accumulators and water accumulators operating at a constant pressure have been employed at electric power stations at Charlottenburg and Göttingen [5]. Operating experience has indicated the reliability and effectiveness of operation of HA in covering electric load peaks.

However, the broad use of HA has been impeded by the absence of economically and technically feasible designs of housings. The proper development of such housings or structures for them is a timely problem even at the present time and must be solved. In the case of large geometric dimensions of the housing (total useful volume 5,000-42,000 m^3) and high parameters of the working medium (pressure up to 6-7 MPa, temperature up to 285°C) the most realistic solution is the creation of a housing for HA from prestressed reinforced concrete (PSRC), which has a number of technological advantages over steel, a high supporting capacity and to the greatest degree ensures operational safety and reliability of the housings fabricated from it.

A comparative analysis of the results of computations of the estimated cost of steel and reinforced concrete housings carried out in the USSR and abroad makes it possible to conclude that the expenditure of steel on the construction of a reinforced concrete housing (including stressed reinforcements, interior jacketing, cover with locking devices) is lower than in the erection of a similar steel structure. According to individual estimates of specialists (for example, specialists in West Germany), the total cost of the prestressed housing for the reactor of an atomic electric power station is 28% less than for a similar metal housing; 55% of the total cost is expenditures on erection of the reinforced concrete part of the structure, 22% is on construction of the hermetic jacketing and 23% on the construction and installation of the cover with the locking devices. With an increase in the dimensions of the reinforced concrete housings the difference in the cost of construction of the housings of the heat accumulators increases. The computations made at the Scientific Research Section of "Gidroproyekt" imeni S. Ya. Zhuk indicate that the use of PSRC for constructing housings for HA makes it possible to achieve a substantial saving of monetary funds because one accumulating apparatus of PSRC, such as with a volume of 5,000 m^3, can replace a system of 15-20 accumulating housings of steel having similar nominal pressure and temperature. Thus, PSRC has come into the broadest use in the construction of the housings of reactors and therefore can be used successfully in creating the housings of heat accumulators (especially accumulators of feed water), operating with lower working parameters of the medium.

Technical-economic computations made in the Scientific Research Section of "Gidroproyekt" and at the Power Engineering Institute imeni K. M. Krzhizhanovskiy have indicated the desirability of using reinforced concrete housings at atomic electric power stations. The cost of peak electric power produced on the basis of nuclear fuel by means of feed water accumulators (FWA) and steam-water accumulators (SWA) is considerably lower than the cost of the electric power fed from the busbars of gas-turbine plants and HAEPS. As an example of use of FWA a study was made of a simple scheme for an atomic electric power station with a VVER-1000 reactor and a K-1000-60 turbine producing electric power without the use of peak turbines.

The technical-economic indices for such an atomic electric power station are given below.

Maximum peak electric power	200 MW
Mean daily production of peak electric power using feed water accumulation	1,000 hours/year
Annual number of hours of use of peak power	1,000 hours/year
Average daily decrease in production of electric power by main loop associated with charging of FWA	630 MW/hour
Average depth of unloading of atomic power station at nighttime	10.4%
Useful volume of FWA	19,000 m^3
Specific capital investments in peak loop	75 rubles/KW
Specific reduced expenditures on production of peak electric power from busbars at atomic electric power station	2 kopecks/(KW·hour)

The cited data show that for the mentioned atomic electric power station the specific capital investments are 75 rubles/KW, and the specific reduced expenditures on the production of peak electric power from the busbars of the atomic electric power station do not exceed 2 kopecks/(KW·hour), whereas for a HAEPS with a power of 1,500 MW these indices are 187 rubles/KW and 2.4 kopecks/(KW·hour) respectively.

It should be noted that the use of HA at AEPS is more promising than at thermal electric power stations because the overexpenditures on the production of peak electric power associated with thermodynamic losses is considerably less at AEPS than at thermal electric power stations (since the expenditures on obtaining nuclear fuel are substantially lower than the cost of organic fuel). For example, when the efficiency of a peak loop with HA is half the efficiency of the main loop the expenditures on the delivery of peak electric power from the busbars of the atomic electric power station increase by not more than 10-15%. At the same time, the use of HA at atomic electric power stations makes it possible to disperse the electric peak power, which precludes the need for constructing powerful electric transmission lines.

The table gives the technical-economic indices of heat-accumulating apparatus with SWA and FWA, hydroaccumulating electric power stations (HAEPS) and peak gas-turbine apparatus.

The investigations indicated that for use at AEPS operating in a saturated steam cycle it is precisely FWA and SWA which are most promising. The authors of this article have developed a number of new schemes for atomic electric power stations with HA, construction plans for housings of PSRC and a method for thermophysical computations of HA, and also made technical-economic computations of the peak loop.

Figure 1 is a diagram of an atomic electric power station with FWA similar to that described in [5]. A distinguishing characteristic of this system is the possibility of producing peak electric power without a peak turbine.

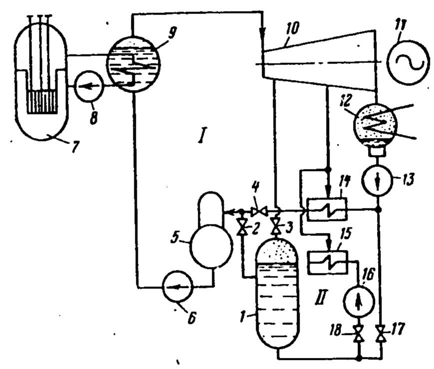

Fig. 1. Structural diagram of atomic electric power station with feed water accumulation. I) main loop; II) peak loop; 1) feed water accumulator; 2-4, 17, 18) slides; 5) deaerator; 6) feed pump; 7) reactor; 8) main circulation pump of first loop; 9) steam generator; 10) main turbine operating in saturated steam cycle; 11) electric generator; 12) condenser; 13) condensate pump; 14) regenerative heaters of main loop; 15) regenerative heaters of peak loop; 16) circulation pump. (Components 1-3, 15-18 belong to the peak loop, the others to the main loop.)

Type of maneuverable power plant	Number of hours of operation per year, hours/year	Specific capital investments, arbitrary units/(KW·hour)	Specific reduced expenditures, arbitrary units/(KW·hour)
GT-100-750	500	80	5.52
	1000	60	3.47
GT-150-1100	500	60	4.41
	1000	60	2.93
HAEPS (fed from AEPS)	1000	160	2.6
	1500	140	1.75
	3000	200	1.35
AEPS with FWA	500	56	2.45
	1000	83	1.83
	1500	110	1.58
AEPS with SWA	500	66	3
	1000	88	2
	1500	110	1.69

During the time of the minimum electric load in the power system the cold water from the lower part of the FWA by means of the peak loop circulation pump is fed to the inlet of the regenerative heaters in the peak loop. As a result there is an increase in steam flow from the regenerative takeoffs from the turbine, which is fed to the entry not only of the regenerative heaters of the main loop, but also the regenerative heaters of the peak loop. This steam heats the cold water, which at a temperature close to the temperature of the feed water is fed into the upper part of the FWA. Thus, there is a decrease in the electric power of the atomic electric power station with a constancy of the thermal power of the reactors, which ensures a reliable passing of the nighttime electric load minimum in the system.

During the period of the electric load maximum the passage of the cold condensate of the turbine through the regenerative heaters of the main loop completely ceases, which leads to a decrease in the steam flow from the regenerative takeoffs and its passage through the "flow-through" part of the turbine into the condenser, and accordingly, additional (peak) electric power is produced. At this time the hot water from the upper part of the FWA is fed to the deaerator and then to the steam generator. The volume of the fed water is equal to the volume of the cold condensate entering the lower part of the FWA through the regenerative heaters of the main loop.

In this system the housing simultaneously performs the function of a FWA and a cold condensate tank (CCT). This makes it possible to ensure a savings in capital investments and a reduction of the area required for placement of the CCT, which in volume is comparable with the FWA.

It can be seen from computations for this system, made applicable to atomic power stations with VVER-1000 reactors, that the specific reduced expenditures on the production of the peak electric power produced by the main turbine by means of the FWA do not exceed 2 kopecks/(KW·hour). The FWA, in comparison with the SWA, has a higher efficiency, but its use is limited by the handling capacity of the last stages of the LPC of the main turbine.

Atomic electric power station systems with SWA ensure a greater unloading of the power station (40-60%) during the period of a minimum load, and accordingly a higher production of peak electric power. However, they differ from atomic electric power station systems with FWA by higher expenditures on the output of peak electric power, which is determined by the greater capital investments due to the use of peak condensation or heat-producing turbines and substantial losses in throttling.

It should be noted that TA also ensure a reliable power reserve. In an AEPS system with FWA (Fig. 1) the peak power is constantly (except for the period of nighttime charging of the HA) in reserve since in producing the peak electric power use is made of the main turbine, which operates around-the-clock. In an AEPS system with SWA and a peak turbine, its generator, cut into the network, can operate in the regime of a synchronous compensator. In this case an insignificant power is required from the network (for rotation of the generator and the peak turbine); a small volume of steam from the SWA is expended on its heating and ventilation.

These investigations revealed the desirability of creating AEPS systems with heat accumulators. However, the realization of these proposals is dependent on the possibility of developing housings of a considerable total volume. For example, for the system with FWA considered above the total volume of the housings is 19,000 m^3 with a condensate pressure up to 2 MPa and a temperature of 200-220°C; for systems with SWA -- 30,000-50,000 m^3 with a pressure 6-7 MPa and a temperature 280-300°C. If we take into account the requirements on ensuring absolute safety and maximum reliability of these housings during the period of operation with sufficiently low capital expenditures on their construction, it becomes obvious that it is a complex undertaking to create AEPS systems with HA and it is understandable why at present there is limited use of heat accumulators at atomic and thermal electric power stations, although interest in the development of such systems is high in all industrially well-developed countries.

In West Germany design work has been carried out for determining the possibility of engineering development of heat accumulators of the FWA type [6]. The useful volume of the FWA was determined by the maximum base power of a 600 MW electric power station with an expenditure of feed water of 480 kg/sec. In order to ensure the daily regime of the heat accumulator (four hours of full load) and expenditure of all the feed water the FWA volume must be 8,500 m^3; in order to ensure heat accumulation on Saturdays and Sundays (approximately 20 hours) -- about 42,000 m^3. On the basis of an analysis of the design decisions and their technical-economic indices the conclusion is drawn that it is impossible to develop housings which are completely made of metal for the entire useful volume of the HA. A study was made of the case of creating a "battery" of 25 steel housings. This solution requires considerable expenditures on their construction. In addition, there is the probability of brittle destruction of some of the housings in the course of operation in variable regimes.

As a variant of the design solution for the housings of thermal accumulators with a computed pressure of 6 MPa and a temperature of 270°C the authors of [6] examine a housing of prestressed prefabricated cast iron circular components with a thickness of 500 mm and a mass up to 3 tons. The internal diameter of such a housing, with a useful volume of 8,000 m^3, is 12 m; the height of the inner volume is 70 m (Fig. 2,a). The "blocks" are joined by keys and grooves (Fig. 2,b); the hermetic integrity of the inner volume is ensured by a steel jacketing. Prestressing in the meridional and annular directions is accomplished by means of streched cables. The heat insulation is on the outside. It is noted that such housings must be used in definite pressure and temperature ranges due to the possibility of brittle destruction because the presence of heat insulation on the outer side of the housings for a number of reasons considerably limits their operation or makes it completely impossible during the sharp transient temperature regimes of charging and discharging the accumulators. Due to their considerable height such housings are vulnerable during seismic and other external dynamic events.

A study was also made of a variant with the placement of the housing in bedrock excavations at a depth of 500 m. In this case the water pressure is imparted to the surrounding mass. The depth of placement of the housing was determined from the condition of an equality of the internal pressure to the counterpressure of the surrounding mass. However, the construction of such a housing involves the necessity of work in bedrock, which is exceptionally time consuming, and it is also difficult to service, inspect and repair it.

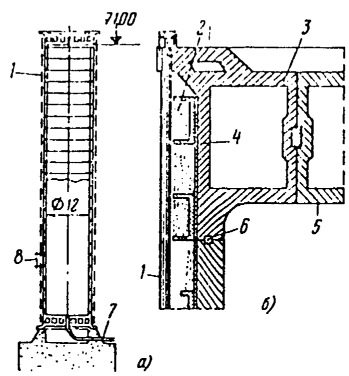

Fig. 2. Prefabricated housing of prestressed cast iron. a) construction of housing; b) prefabricated component: 1) vertical reinforcement; 2) circular reinforcement; 3) upper cover; 4) insulation; 5) inner jacketing; 6) "key"; 7) pipe; 8) annular component of cylindrical wall.

A real alternative for the creation of the housings of heat accumulators is the development and use of high-pressure housings of prestressed reinforced concrete, in its parameters corresponding to the requirements of safety, reliability and technological efficiency with sufficiently low expenditures on their construction and operation. Heat accumulators require housings of prestressed reinforced concrete with a useful volume of 10,000-15,000 m^3 or more with a pressure of the medium 6-7 MPa and a temperature up to 280°C.

In some countries (especially in England and France) several atomic reactors which have housings of PSRC have been constructed [7].

For example, at the atomic electric power stations Hunterston B and Oldbury (England) reactors have been constructed with volumes 5,200 and 7,500 m^3 with pressures of 4.22 and 2.46 MPa; Bouches and Saint Laurent (France) -- reactors with volumes 8,800 and 10,300 m^3 with pressures of 4.75 and 3.23 MPa respectively.

These examples show that the housings of reactors constructed in France are close in volume and pressure level to the housings of heat accumulators developed in West Germany. However, the pressure level attained in these housings is lower than is necessary for SWA (6.2-6.5 MPa at a temperature of 280°C).

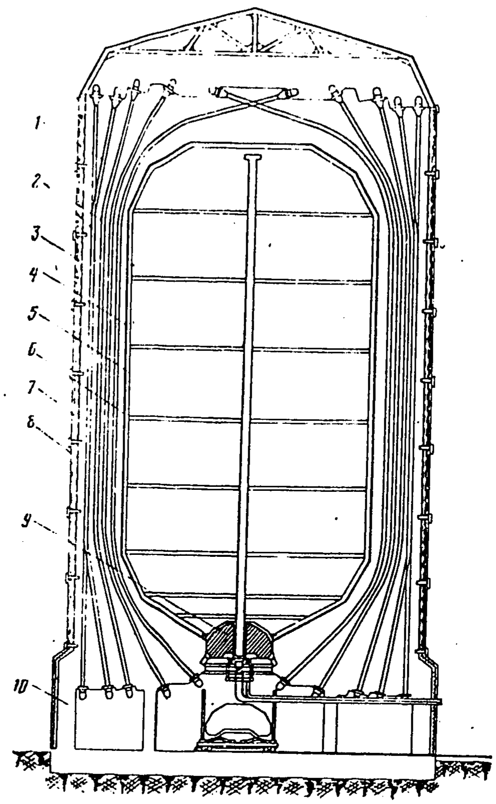

Fig. 3. High-pressure housing of PSRC for heat accumulator. 1) housing of PSRC; 2) bundles of high-strength cable wire with stress 9000 KN; 3) high-strength reinforcement with diameter of 5-6 mm for winding; 4) internal heat shielding of housing; 5) hermetic steel jacketing; 6) constructive steel shell; 7) external insulation of housing; 8) protective steel jacketing; 9) reinforced concrete cover of housing; 10) housing foundation

In the development of construction plans for housings of heat accumulators the emphasis was on the designing of cylindrical housings with a useful volume of 5,000 and 10,000 m^3 with a pressure up to 6-7 MPa and a temperature of the working medium 270-300°C. On the basis of an analysis of variants of configurations of housings in the form of a cylinder (types

VK-500, VK-2000, Bouches, Saint Laurent), spheres (Wilph type), a cylinder with a toroidal internal cavity and others the conclusion was drawn that a housing of cylindrical configuration with a flat bottom is best studied from the point of view of creating a stressed state of cc-.rete and the organization of work production. At the present time the fabrication of reinforced concrete housings of such a configuration is supported by experimental and computational-theoretical investigations of a prestressed reactor housing, related to the problem of creating ATEPS with a boiling reactor, work done at the Scientific Research Department "Gidroproyekt" imeni S. Ya. Zhuk. The reliability and safety of such structures have been demonstrated by the experience of foreign construction.

Thus, for creating housings of heat accumulators with a pressure of 2-6 MPa it is desirable to use prestressed reinforced concrete because this material has high technological advantages, a high supporting capacity, and to the highest degree meets the requirements of operational safety and reliability.

Figure 3 shows a cylindrical housing for a heat accumulator with a useful volume of 5,000 m^3, having the following parameters:

Internal working pressure	Up to 7 MPa
Temperature of working medium within housing	276°C
Computed maximum temperature of concrete	60°C
Internal diameter	15 m
Height of internal volume	31.8 m

The supporting housing is made of PSRC and is rated as a "construction of the first category of fissure resistance," which forestalls the possibility of the formation of fissures in the concrete irrespective of the combinations of loads. The strength of the housing is ensured by prestressing of the concrete. Under the extremal conditions of a sudden increase in stresses or an increase in strains in the housing (pressure decreases but the temperature remains at the maximum computed level) there is no uncontrollable sudden destruction of the concrete. The safety factors established as a result of computations and tests of models of housings are 2.5-3.

In order to create prestressing of the housing concrete provision is made for the use of an effective method for continuous reinforcement ("winding") in combination with the use of a system of discrete reinforcement by bundles in an axial direction with a total concentrated stress up to 10,000 KN.

The operational reliability of the housing is ensured by a thermal protection and hermetic jacketing. The heat shielding, consisting of a heat-insulating covering and a cooling system, makes it possible to maintain the temperature of the supporting concrete at the level 60-65°C, as a result of which the strength of the concrete is reduced insignificantly and no

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significant thermal stresses arise. In the heat accumulators it is simpler to maintain the set temperature regime than in the housings of reactors due to the absence of heat release in the concrete from gamma radiation.

A hermetic sealing of the internal cavity of the high-pressure reinforced concrete housing is ensured by a two-layer system of closed steel jacketings playing a role jointly with the concrete structure and the heat insulation. The possibility of significant fracturing of the jacketing as a result of exposure to working loads is prevented by an anchoring system limiting deformations of the sheathing, by the elastic resistance of the concrete structure and the selected compressional stresses.

Conclusions

1. Heat accumulators in the form of FWA and SWA are economically feasible for use at atomic electric power stations already in existence and at those which are under construction. The capital investments in this case are 40-60 rubles/KW and the specific reduced expenditures on the production of peak electric power do not exceed 2 kopecks/(KW·hour).

2. Thermal systems for connection and use, and also the construction of housings of PSRC for heat accumulators are presently technically feasible.

3. The use of SWA makes it possible to ensure the unloading of atomic electric power stations to 40-60% when there is a peak turbine of the corresponding power.

4. The use of heat accumulators in the form of FWA or SWA is also desirable at atomic electric power stations of a low power in regions where such electric power stations are the principal power source and cover all electric load zones.

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ELECTRIC POWER

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CONSTRUCTION DIFFICULTIES OF OVERHEAD LINES ALONG BAYKAL-AMUR RAILROAD LINE

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 2, Feb 80 pp 48-49

[Article by Engineer G. P. Sivoklokov]

[Text] The organization and implementation of work on constructing overhead lines and substations under the geological engineering and climatic conditions along the Baykal-Amur Railroad Line involve definite difficulties. For the successful implementation of construction with the stipulated deadlines and for ensuring the proper work sequence in carrying out this work by flow methods with the maximum use of the work force and equipment and minimum work expenditures it is necessary to solve a great many problems and in particular, develop a plan for the organizational and engineering preparation of construction work, which includes:

-- analysis of planning decisions, including the engineering-technical effectiveness of the construction work;

-- organization of the construction of individual parts of a project (determination of the site of installation sectors and the placement in these sectors of temporary buildings, warehouses, places for the putting together of construction parts, parking sites for vehicles, sources of electric supply, places for repairing construction equipment, and also preparation of flowsheets for the movement of equipment, etc.);

-- working-through of procedures for carrying out work for an integral part of the project or an individual type of work with the formulation of technological models, determining the variety of basic mechanisms and apparatuses and the number of workers and preparation of schedules for their work;

-- complete supplying of the individual parts of the project with material resources in accordance with the worked-out technological scheme;

-- formulation of a technological model for the entire range of the work carried out by flow methods.

In the plan for organizational-engineering preparation of construction work an individual work project is regarded as a complex of several structures (OPU, OPU, ZRU, anchored span, etc.) or types of work done in a large volume (construction of ORU portals, foundations under equipment, etc.). Accordingly, it contains a corresponding number of organizational-engineering flow charts. Such a chart, together with a complete and detailed project breakdown chart, constitutes a self-contained and independent document necessary for organizing work production and its safe implementation.

In drawing up such project organizational-engineering charts special attention is devoted to the use of advanced technology, proper sequence and procedures for carrying out the work, effective equipment and vehicles, minor equipment, apparatus and gear, which makes it possible to ensure a high quality of work performance.

The sequence for carrying out the work and the possible combining of different types of work are indicated in a technological model, which is constructed at a time scale. In such a model the work parameters are determined with allowance for the number of shifts, number of workers, productivity of construction work and work volume. In accordance with the technological model specialists prepare a schedule for the operation of the main equipment and detailed breakdown flowsheet for the construction and materials for different kinds of work.

The technological models for subprojects are combined into a technological model for construction of the entire project, in which provision is made for the flow-type construction of units and the times for ending the stages and the projects as a whole are stipulated. Thus, the technological model of construction makes it possible to carry out the entire complex of work, to plan work and resources, and routinely solve problems related to the movement of resources from project to project when there are possible deviations in the course of construction.

The advantage of the individual project form of organizational-engineering documentation is the possibility of its repeated use in standard solutions for parts of construction projects and also the incorporation of a convenient and purposeful system for supplying individual work projects with material-technical resources.

The repeated use of such planning decisions in subsequent construction sectors facilitates the organizational-engineering preparation of projects, reduces the time spent in choosing methods for carrying out the work with the necessary variety of material-technical and human resources, as is particularly important when there are limited times for beginning the preparation of construction on a project. As is well known, precisely in the period of construction preparation there is the greatest number of inaccuracies in the organization and implementation of work, this is the period when the shortage of material-technical resources is felt, etc., which results in great nonproductive expenditures which can negate all the progressive and economical decisions introduced in construction of the projects. In addition, the individual work project form of organizational-engineering documentation is suitable when introducing crew commitments.

On the basis of experience in making preparations for and constructing overhead lines and 220-500 KV substations in the Ural and Western and Eastern Siberian regions, the Novosibirsk Affiliate of the Orgenergostroy Institute has carried out projects for the organizational-engineering preparations for constructing the first segments of overhead lines and substations for electric supply of the Baykal-Amur Railroad Line. These plans are now being used in other regions of construction of overhead lines and substations.

The introduction of such project supplying of materials and manpower and the plans developed for implementing work at projects on the Baykal-Amur Railroad make it possible to carry out work in accordance with the time plan, reduce work expenditures by 30% due to elimination of nonproductive expenditures and introduce a progressive work program, putting all parts of the construction into operation on time. For example, the introduction of the enumerated measures for two segments of the 220-KV overhead line with an extent of 259 km and one 220-KV substation under the difficult construction conditions alone made it possible to reduce work expenditures by 66,800 man-days and thereby ensure a saving of 370,000 rubles (see table).

Table

Work project	Reduction of work expenditures, thousands of man-days	Savings. thousands of rubles
Substation 220/110/35/10 KV, Tynda	22.2	110
Overhead line, 220 KV, Tayura-Kirenga-Baykal tunnel	22.8	129
Overhead line, 220 KV, Baykal tunnel-Nizhneangarsk	21.8	131

Thus, the organizational-engineering preparation of construction of electric power projects must become the basis for organizing accelerated-flow-type construction and timely putting of the projects into operation.

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ELECTRIC POWER

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PLAN FOR 220-KV OVERHEAD LINE BETWEEN TYNDA, PRIZEYSKAYA

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 2, Feb 80 pp 53-55

[Article by G. G. Kirillova and A. N. Volkov]

[Text] The plan for the 220-KV overhead line between Tynda and Prizeyskaya, prepared by the Tomsk Division of Energoset'proyekt Institute, included the crossing of this electric power line over the reservoir of the Zeyskaya Hydroelectric Power Station.

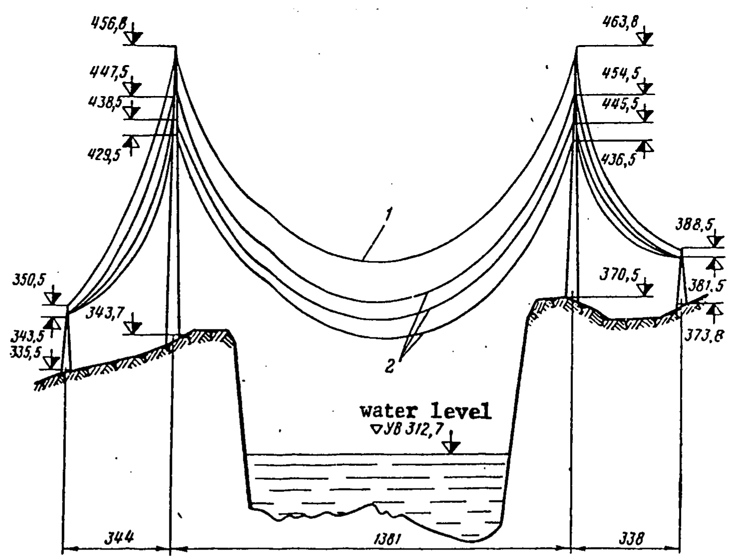

Fig. 1. Diagram of crossing. 1) S-300 cable; 2) AS 500/336 wire.

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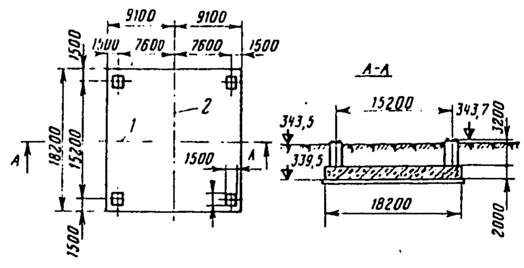

Fig. 2. Foundation under left-bank crossing tower. 1) axis of overhead lines; 2) axis of traverses

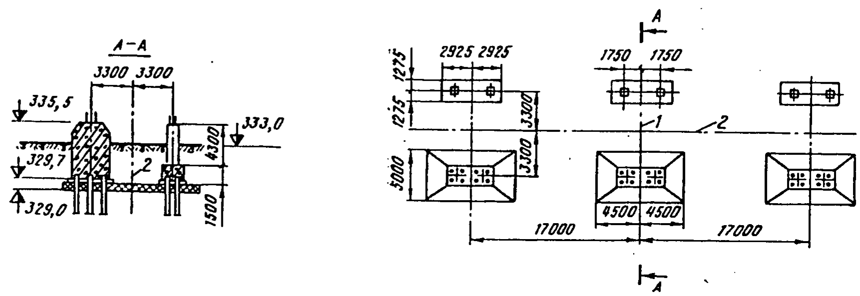

Fig. 3. Foundations under left-bank final support. 1) axis of overhead lines; 2) axis of traverses

After filling of the reservoir the choice of the crossing line was narrowed down to the neighborhood of Prizeysk (near the constructed railroad bridge), where the distance between the high banks was minimum. Initially a study was made of two fundamentally different variants of the crossing: passage of the overhead line along the railroad bridge and construction of a crossing below the bridge at a distance of 200 m. It was necessary to discard the first variant because the loads on the railroad bridge, taking into account the passage of the overhead line along it, exceeded the computed tolerances. In addition, in this case there is considerable complication of operation of both the bridge and the overhead line itself.

The second variant was selected as the better. In choosing the crossing plan a study was made of five variants. In order to ensure the necessary dimensional distances and a rational expenditure of metal use was made of a final support-crossing tower-crossing tower-final support scheme Fig. 1).

The width of the selected crossing line over the reservoir surface is 985 m.

The crossing towers were situated 150 m from the bank brows. The crossing span is 1,381 m. On the right bank the final supports were distant from the crossing towers by 338 m and on the left bank by 344 m. The total length of the crossing was 2,063 m.

The computed span was adopted taking into account the possible deformation of the banks and the conditions for operation of construction machinery.

The climatic conditions in the crossing region and the computational data are cited below:

Temperature:	
coldest five-day period	-11°C
with glaze	-10°C
Wind velocity:	
maximum (to height of 10 m)	30 m/sec
computed for wires	40 m/sec
computed for cables	42 m/sec
for glaze	15 m/sec
Thickness of glaze wall:	
for wires	20 mm
for cables	25 mm

In accordance with the computations, in the crossing project use was made of AS 500/336 wire with $\sigma = 247.5$, $\sigma_{el} = 168$ and $\sigma_{rot} = 550$ MPa; as lightning-arresting wires (Group ZhS) -- with a tensile strength 1,200 MPa. The computed value, equal to 590 MPa, was selected in accordance with the normalized distance between wire and cable in the middle of the span (19.5 m) as determined by the Specifications for the Layout of Electrical Installations.

On the right bank plans called for a crossing tower with a height of 100 m with suspension of the lower wires at the level 70.0 m; on the left bank -- a tower with a height of 120 m with suspension of the wires at the level 90.0 m.

Due to temperature conditions the towers had to be fabricated from low-alloy steels, as a result of which standardized crossing towers could not be used. The standard PP330-2/70 crossing tower was the closest with respect to design specifications and admissible loads under the given conditions. In drawing up the plan for the right-bank crossing tower it was adopted as a basis. An individual plan was developed for the left-bank crossing tower.

Both towers were of the lattice type with a tetrahedral shaft of square cross section. Taking into account the conditions for transport the components of the towers were designed with bolt connections (upper sections attached by bolts of normal accuracy, lower -- with bolts of increased accuracy). Only the upper sections of the shafts were welded (their dimensions do not exceed "railroad dimensions"), and also the components of ladders and platforms for ascent on the crossing towers and for servicing the safety lights.

The principal indices of the crossing towers are given in the table.

Type of crossing support	Height to lower traverse, m	Total height of tower, m	Tower base, m	Mass of support, tons	Type of wire	Type of cable	Thickness of glaze wall, mm	Wind velocity head (region IV), N/m^2
PP220-2/70	70	100	13 x 13	149.8	6xAS500/336	2xS-300	15	560
PP220-2/90	90	120	15.2 x 15.2	225.7	6xAS500/336	2xS-300	15	560

The K220-2 final supports constitute a construction consisting of three individually freely standing supports each with a height of 24.5 m. Two wires were attached to each support and lightning-arresting cables were attached to the outermost supports. It was proposed that the supports be fabricated of 09G2S-12 steel.

The foundations under the supports were placed on high banks not flooded by high waters. The ground water level at the site of the foundations was high. The ground was spongy.

Bedrock was situated under the right-bank supports and the left-bank crossing tower at a depth of 4-5 m. With this taken into account, the foundations of these three supports had to rest directly on the bedrock.

In selecting foundations under the crossing towers two variants were considered: under each leg of the support and a common foundation under the entire support in the form of a continuous slab with four reinforced concrete supports under each leg of the tower.

The total volume of the concrete in the foundation laid under each leg of the support is 879 m^3 (right bank) and 836 m^3 (left bank), in the continuous foundation -- 761 and 692 m^3 respectively. The considerable mass of the foundations is attributable to the great tugging loads and the suspension effect of ground water. As can be seen from these data, continuous foundations under the entire support are most economical (Fig. 2).

It was decided that massive foundations be placed separately under each leg under the right-bank final support. The expenditure of concrete on such foundations was 770.6 m^3.

Under the left-bank final support plans called for foundations on a pile base with massive reinforced concrete grillage (Fig. 3). The choice of such a foundation construction was dictated by the presence of permanently frozen sandy loams and the absence of bedrock directly under the support to a depth of 10 m. The length of the piles was 8 m; the section measured 36 x 35 cm. The piles were driven into predrilled boreholes. The number and type of piles were determined taking into account the external loads and ground conditions.

It was recommended that the boreholes be drilled and the piles be driven in winter, which makes it possible to avoid a sagging of the active layer. In order to preclude heat transfer to the base of the foundation through the massive grillage and its settling it was provided that underneath the grillage there should be heat insulation of "keramzit" (porous clay filler) gravel with a thickness of 500 mm. In order for the piles to be frozen in the boreholes, whose diameter exceeds the diameter of the piles, are drilled first. Then the borehole to approximately one-third of its depth is filled with "pulp" -- a mixture of the slurry removed from the borehole and a clayey solution prepared in a special composition.

All the foundations and grillage were planned for construction with monolithic concrete. The compressional grade of concrete was 200, the frost-resistance grade was 200, the water impermeability grade was V-4. In order to reduce frost heaving forces the backfilling of excavations was with nonheaving ground.

In doing the work on laying of the monolithic reinforced concrete foundations under a support it is necessary to carefully monitor the quality of the concrete, which must correspond to the requirements with respect to frost resistance.

In order to reduce the volumes of concrete work there can be a variant with the embedding of anchors in bedrock. This problem will be finally solved after carrying out additional field work and tests. According to preliminary computations the use of anchors will make it possible to reduce the volume of monolithic reinforced concrete by a factor of 1.3-1.5.

5303
CSO: 1822

ELECTRIC POWER

UDC 621.039.5.621.79

EQUIPMENT FOR ATOMIC ELECTRIC POWER STATIONS WITH VVER-440 REACTORS

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 2, Feb 80 pp 55-56

[Article by Engineer E. I. Gomberg]

[Text] The standardized layout of atomic electric power stations with VVER-440 reactors provides for the arrangement of the basic equipment of the reactor section in hermetically sealed enclosures and its servicing with bridge cranes having a lifting capacity of 250 and 30 tons. The equipment in the machine room is serviced by two bridge cranes with a lifting capacity of 25 tons each.

The most important heavy-weight equipment -- the reactor housing, apparatus within the housing, volume compensator, emergency cooling hydraulic system (ECHS) -- is delivered to the construction site in a horizontal position in factory crating using special transport facilities. It is unloaded in the transport corridor of the reactor section and its tilting (placement in proper position) (depending on the mass of the equipment) is at the zero level or at the level 18.90 m.

Installation experience has shown that the delivery of equipment to the reactor section is through a transverse entrance and therefore for reducing expenditures of time and work in installation it is necessary to reduce the volume of work on the unloading of the equipment and preclude the operation of its tilting at the zero level, which involves much work.

The vertical equipment in the machine room (high- and low-pressure heaters, separators - steam superheaters) is delivered in a horizontal position via a temporary transport entry along level A. The tilting of this equipment is on the foundation slab of the machine room.

The difference in the masses and designs of the main equipment dictated the specifics of its tilting and also required the development and fabrication of individual installation apparatus and rigging.

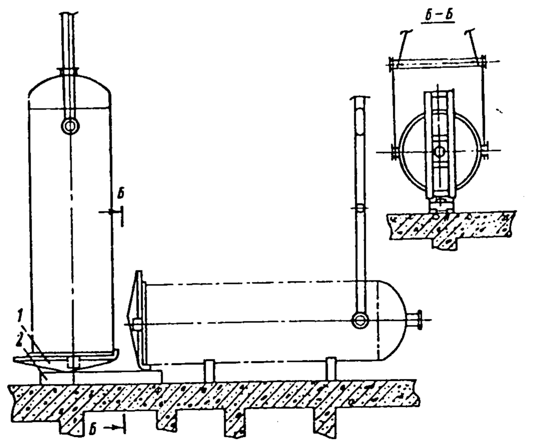

Fig. 1. Reduction of equipment to a vertical position on a tilter.

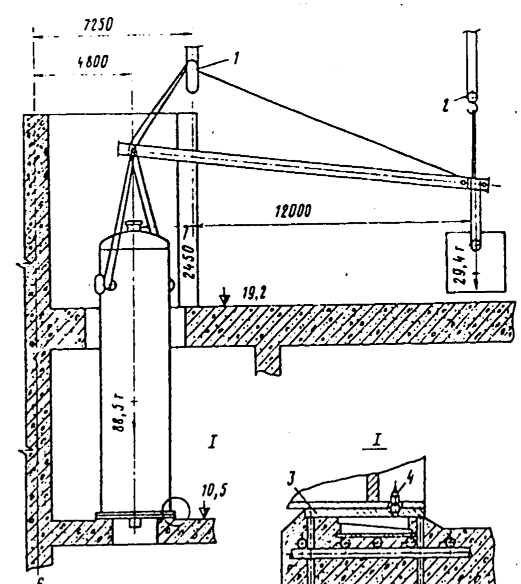

Fig. 2. Installation of volume compensator using a traverse with a counter-weight. 1) extreme position of hook with a lifting capacity of 250 tons; 2) hook of crane with a lifting capacity of 30 tons; 3) adjustable flange; 4) catch.

In accordance with the installation procedures developed at the Kiev Affiliate of the Energomontazhproyekt Institute for the Rovenskaya Atomic Electric Power Station, the unloading of the heavy-weight equipment provided for the work to be done in the transport corridor by means of bridge cranes of the reactor section and that the tilting be done in the central room using special standardized installation apparatus. In developing a method for tilting the equipment and constructing the mentioned apparatus an allowance was made for the mass and configuration of the lower part of the equipment and therefore there was no need to carry out strengthening of construction members of the building at the level 18.90 m.

For example, the housing and bottom of the reactor (mass 220 and 30 tons respectively), having an elliptical base, were put into a vertical position by a crane with a lifting capacity of 250 tons on a footing. The horizontal dimensions of the footing were 5000 x 1200 mm and the height was 650 mm; it received a load of 1100 KN when tilting the housing and 2200 KN when the operation was completed and imparted the load to the supporting walls of the structure at the 18.90-m level.

The upper block (its mass with the crating was 150 tons), the reactor shaft (38 tons), the basket (22 tons), the volume compensator (127 tons) and four ECHS (each 88.5 tons) were put into a vertical position using the tilter 1, which rested on the footing 2 (Fig. 1).

The volume compensator and the ECHS units are delivered to the installation site with adjustable flanges which are connected to them by special pins but which must be welded to the foundations.

In the adopted installation procedures provision was made for tilting (proper positioning) of the volume compensator and the ECHS, separation of the adjustable flanges from the equipment and their precise placement in the planned sites on wedges. After alinement in the horizontal plane the flanges are welded or concrete is poured over them, after which three catches are screwed into the threaded openings. The volume compensator and the ECHS are placed at the level 10.50 m through installation openings in the walls and the tops of the enclosures at the level 26.50 m.

A feature of the procedure for installation of the volume compensator and one ECHS, situated outside the extreme range of the bridge crane with a lifting capacity of 250 tons, is the use of a traverse with a counterweight (Fig. 2), constructed in the form of a thin block with a mass not greater than 29.4 tons.

The distance from the extreme range of the crane hook with a lifting capacity of 250 tons to the axis of ECHS installation is 2450 mm, and to the axis of the volume compensator (in mutually perpendicular directions) -- 250 mm. Despite such an insignificant distance it is impossible to handle the volume compensator, having a maximum diameter of 3800 mm, on the crane hook because the diameter of the opening at the level 18.90 m is 3900 mm.

In order to install the volume compensator or ECHS in the planned position the traverse had to be slung on the hook of a crane with a lifting capacity of 250 tons and the counterweight was slung on the hook of a crane with a lifting capacity of 30 tons and they were lowered onto the catches.

The remaining equipment of the reactor section with a flat base (upper block, shaft, basket) after tilting is set in the planned position by a crane with a lifting capacity of 250 tons or by standard clamping of the protective cylinder.

For tilting of the heavy-weight equipment in the machine hall (ten LPC each weighing 21 tons, six HPC each weighing 89.5 tons and four separators-steam superheaters each weighing 107 tons) it is also feasible to use a tilter with a footing or without it (if the tilting takes place on the foundation slab of the machine room).

Thus, the procedures developed at the Kiev Affiliate of the Energomontazhproyekt Institute make it possible to standardize the tilting and installation of the main equipment in the reactor and machine rooms, reduce the number of installation apparatuses and lessen the volume of transport and rigging work, which will make possible a considerable reduction of work expenditures on the installation of complex equipment, which is very time-consuming.

5303
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ELECTRIC POWER

UDC 621.662.67

USE OF OIL SHALE TO PRODUCE POWER

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 4, 1980 pp 28-30

[Article by engineers B. I. Tyagunov, V. I. Panov, G. P. Stel'makh: "Power Engineering Utilization of Oil Shale"]

[Text] In recent years the problem of the comprehensive use of oil shale as a source of energy and manufacturing resources for petrochemical enterprises has become particularly acute.

Oil shales are one of the most widespread types of solid fuel and manufacturing resources. However, using shales is impeded because of their high ash content (60-70 percent and more). It is known that it is possible to produce shale oil (a petroleum substitute), gases containing hydrocarbons and otherproducts from oil shales using heat treatment methods.

In the Soviet Union, shales are widely used as fuel, not only at small and average sized TES and TETs, but at large GRES as well.*/ Many of the technical difficulties with burning Baltic shale in TP-67 and TP-101 boiler burners with steam output of 320 tons per hour have been overcome at the Pribaltiyskaya and Estonskaya GRES, which were brought up to rated output in 1973. These GRES produce inexpensive electric power [0.7-0.8 kopeck/(kWt-hr)], due primarily to the low cost of shale (11-12 ruble/ton--converted to conventional fuel).

However, when both electric power stations were in operation at the total rated output of 3035 MWt, about 3700 men were engaged in repair operations, primarily to the boiler equipment and fuel facilities in 1978. Expenses for repair operations were 1 ± 0.02 ruble/ton of natural fuel burned (about R 20 million per year), while metal consumption was 0.6 kilogram per ton of shale (14,200 tons per year).

*/ Kuznetsov, D. T. "Energokhimicheskoye ispol'zovaniye goryuchikh slantsev [The Power and Chemical Use of Oil Shales]." Moscow, Energiya, 1978. 250 pp.

Direct combustion of shale is also associated with significant atmospheric pollution from dusty ash and sulfur dioxide. The above GRES annually discharge more than 120,000 tons of dusty ash and 250,000-320,000 tons of sulfur dioxide into the atmosphere. For this reason construction of new power plants with direct shale combustion is not permissible in the Baltic shale basin because of sanitary conditions.

The economic expedience of significantly expanding the mining and the use of shales from the Baltic basin to produce energy makes it necessary to find the most rapid solution to the problems of protecting the atmosphere and eliminating technical difficulties while insuring the operation of shale (fired) electric power stations under semi-peak and peak operating conditions.

Presently only one means is available for solving these problems--employing an energy-producing scheme for producing shales which specifies that they be heat-treated with the aim of producing liquid (shale oil) and gas (semicoke gas) high-calory, low-sulfur fuels as well as raw materials for chemical plants.

The necessity for developing a new technology for heat treatment of shales is brought about by the fact that all known methods specify processing exclusively of lump shale and are inadequately efficient.

A method for heat-treating shales with a solid coolant has been proposed by the Power Engineering Institute imeni G. M. Krzhizhanovskiy. The method was finished and put into operation using the active UTT-500 industrial installation together with the ESSR Academy of Sciences' Institute of Chemistry, the "Kiviyli" Shale and Chemical Combine and the Shale Scientific Research Institute of the USSR Ministry of the Petrochemical Industry. Further design developments for an industrial unit with an output of 3,000 tons/day (UTT-300) at the Estonskaya GRES's pilot plant, as well as an evaluation of this method for the level of technical and economic justification (TEJ) under industrial conditions were carried out by the Leningrad department of the Teploelektroproyekt Institute, the Leningrad branch of the Orgenergostroy [All-Union Institute for the Design and Organization of Power Construction] Institute, as well as by Lengiproneftekhim [Leningrad State Institute for the Design of Petrochemical Plants], VNIPIneft' [All]Union Scientific Research and Design Institute of the Refining and Petrochemical Industry] and other design organizations of the USSR Ministry of the Petrochemical Industry.

The essence of the new method is as follows: dried, fine-grain shale is continuously mixed with a hot ash-coolant and is decomposed at a temperature of about 500 °C away from air.

As was mentioned, this method was developed both technologically and in design at the experimental-industrial UTT-500 installation, with an output of 500 tons of shale per day, which has been in use since 1964. By

1 September 1979 the unit had been in operation about 100,000 hours (under operating and experimental conditions). About 2 million tons of Baltic shale have been processed there during this time.

Reliable production data have been obtained during the lengthy operating period for the unit, and design decisions which had been incorporated into the UTT-3000 pilot project for the industrial unit, consisting of 2 units for processing oil shales for power production, have been tested. This facility is being built at the Estonskaya GRES in accordance with decisions of the 25th Congress of the CPSU, a decree of the USSR Council of Ministers and decisions of the USSR State Committee on Science and Technology. It is planned to put this facility into operation during 1980.

Presently operations for starting up 2 units with a capacity of 3,000 tons of shale per day are being completed at the Estonskaya GRES.

A flow chart of the UTT-3000 installation is shown in Figure 1.

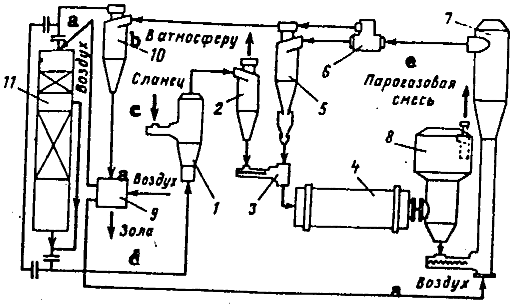

Figure 1. Flow sheet for heat treatment of Baltic shale in the UTT-3000 installation.

Key to Figure 1.

a. air
b. to the atmosphere
c. shale
d. ash
e. steam and gas mixture

The raw shale (up to 20 mm in size) is fed into an aeration fountain dryer 1 by two specially designed worm conveyers, where it is dried and heated to 100-120°C in a rising current of flue gases (with an initial temperature of about 600 °C) in an aerosuspension. The shale enters into dry shale dust extractors 2, where it is separated from the drying agent, and then is fed into mixer 3 (installed at the entrance to a drum reactor 4) by work conveyors. Here the coolant (the ash from the shale being processed) also enters from dust separator 5 at a temperature of 800-850 °C. As a result of mixing the shale with the coolant, the process of thermal decomposition of the shale occurs in the reactor, away from air, at 480-500 °C, with the liberation of shale oil vapors, pyrogenetic water and semicoke gas. The steam and gas products from shale decomposition have the dust removed from them in dust separators situated within chamber 8 (two strands with four purification stages each), and enter the condensation section (not shown in the diagram), where the steam and gas mixture is cooled and the oil products and pyrogenetic (tar) water are removed from it. The solid phase (the mixture of the coolant and semicoke) passes from the reactor, through the chamber, into a work conveyor and is fed into an aeration fountain production furnace 7 for combustion of the fuel part remaining in the semicoke and reduction of the temperature potential (800-850 °C) of the coolant. Air, heated (to 400 °C) in the heat exchanger for the ash 9, is fed into the lower part of the furnace. This air provides pneumatic transport of the solid phase through all of the installation's units, in addition to the complete combustion of the semicoke.

After the furnace, the flow of the ash aerosuspension and flue gases passes through by-pass 6 regulating the passage of the coolant flow into the reactor through the coolant dust separator 5 and diverting the excess amount of ash into dust separator 10, which has three purification stages. The ash from this dust separator passes through the heat exchanger for the ash into a water-type ash trapping system. Air which is fed into the production furnace and the boiler-recovery unit 11 is heated in the heat exchanger. The residual potential and physical heat of the flue gases, from which the ash was removed in dust purifier 10, is used in this boiler-recovery unit. The flue gases, which are cooled in the boiler-recovery unit to 600 °C, enter dryer 1 and then the dry shale dust separator, and are discharged into the atmosphere after decontamination in an electronic filer at 150 °C. The boiler-recovery unit is designed to produce steam at a pressue of 4 MPa and temperature of 440 °C.

The following quantities of products (thousands of tons) are produced from 1 million tons of shale with Q_H^P= 184,000 kJ/kg on a single UTT-3000 unit:

Shale oil with Q_H^P=38,094 kJ/kg..............................	129.4
Semicoke gas with Q_H=39,858 kJ/kg..........................	46.2
Natural gasoline with Q_H=41,370 kJ/kg......................	7
Steam (4 MPa, 440 °C) with allowance for consumption for in-house requirements..................................	150
Tar (Phenol) water..	23.1

The efficiency of the power-producing process 86.3 percent, taking production losses into consideration.

It is possible to produce 40,000 tons of gas turbine fuel (48,000 tons when converted to conventional fuel) from the indicated amount of fuel oil. This is adequate to insure a year's supply of fuel for one GT-100-750 turbine. The gas turbine liquid shale fuel was tested on an experimental GT-15 turbine by the Central Scientific Research, Planning and Design Boiler and Turbine Institute imeni I. I. Polzunov in 1973. Industrial testing of this fuel in the GT-100-750 turbine will become possible only after start-up of the power-producing unit at the Estonskaya GRES.

The semicoke gas, containing unsaturated hydrocarbons (about 36 percent by volume or 50 percent by weight), and the so-called natural gasoline, which is one of its components (0.2 kg per cubic meter of gas) are valuable chemical resources for producing ethylene, propylene, butylene, divinyl, benzol, toluol and phenols.

The power-producing scheme for using shales and questions of its incorporation have been examined more than once at sessions of the Scientific and Technical Council and the USSR Ministry of Power and Electrification's working commission on new technology. The efficiency of this scheme and the advisability of its industrial application to replace direct shale combustion were pointed out in resolutions adopted by them.

It has been presently established that it is necessary to carry out further construction of shale (-fired) electric power stations following the power-producing scheme.

We have results from a technical and economic comparison between the variant employing direct combustion of oil shales and the power-producing scheme for their use, not considering production processing of a part of the products, which was made by the Leningrad department of the Teploelektroproyekt Institute. These results are presented in the table.

Indicator	Direct combustion	Energy-producing scheme
Possible rated GRES output, MWt	1200-1600	limitless
Power unit rating, MWt	200	500-650
Number of hours used per year	3000	3000
Specific fuel consumption of GRES, year/(kWt-hr)	427.5	355
The same, taking into consideration heat for shale processing	---	423
Specific capital investment in construction of the GRES, ruble/kWt	160	102.2
The same, taking into consideration construction for shale treatment	---	140
Work force coefficient at GRES, considering number of repair personnel, men/MWt	1.8	0.44
The same, considering number of personnel engaged in shale processing	---	0.9
Production cost for power produced, kop./(kWt-hr)	1.4	1.14
Adjusted specific expenditures, kop./(kWt-hr)	2.1	1.6

Thus, introduction of the power-producing scheme for using shale will permit us to reduce capital investments by $ 20 million and the number of staff personnel (including repair) by 900 persons per million kilowatts of rated semi-peak output. The savings in the adjusted costs (for an electric power station operating on Baltic shale) is equal to 0.5 kopecks/kWt-hr, or R 5 million per billion kWt-hr of electric power produced.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200100026-0

The possibility for using poor shales with a heat of combustion equal to 6300 kJ/kg and less, whose direct combustion is inefficient and often impossible for practical purposes, for power production is a further advantage of the power-producing scheme.

In 1976-1977 the Leningrad department of Teploelektroproyekt, together with Giproshakht [State Institute for Mine Layout] Institute and organizations of the USSR Ministry of the Petrochemical Industry worked out a technical and economic justification of the advisability for expanding the mining and use of Baltic shale in the national economy to 65 million tons per year (including 50 million tons for processing for power production), with an increase in the output of electric power stations operating on shale fuels to 7,000-8,000 MWt and renovation of the Estonskaya and Pribaltiyskaya GRES with the aim of converting them to burn shale oil. Moreover, the production use of semicoke gas and natural gasoline was specified. It is possible to produce 1,659,000 tons of chemical products, including the following (thousands of tons) from 50 million tons of shale:

High and low density polyethylene	575
Polypropylene	422
Propylene	142
Butylene fraction	272
Liquid propane	94
Divinyl	77
Aromatic hydrocarbons	64
Phenols	13

It would be required to expend more than 3.3 million tons of a petroleum raw material to produce this amount of product according to existing technology.

Considering the possibility for obtaining about 2 million tons of gas turbine fuel, employment of the power-producing scheme for processing 50 million tons of shale permits us not only to provide the power units operating under semi-peak conditions with a total output of 7 million kWt with liquid fuel and to satisfy the fuel requirements of gas turbines having a total output of 5 million kWt, but to save more than 5 million tons of oil and production petroleum resources at the same time.

The economic savings from erecting a power-producing complex using 50 million tons of Baltic shale, as compared with the separate production of electric power at electric power stations with direct fuel combustion and chemical products from a petroleum resource was determined to be

R 11.6 million in the technical and economic justification (based on adjusted expenses, without considering the savings from using the ash).

Given the power-producing use of shale, sulfur dioxide and ash dust emissions into the atmosphere are 5 times less than when direct combustion of shales is employed. This is due to the fact that when shale is processed to be used for power production, 90-92 percent of the sulfur from the original shale remains in the solid residue (the shale ash), whereas this residue contains only 50-65 percent of the sulfur when direct combustion is used. Reduction of ash emissions is associated with the fact that the quantity of incinerated gases to be purified is 5-6 times less when the shales are used for power production than when they are burned directly.

The content of nitrogen oxides in the flue gases when shale oil is employed is less than when shale is burned (directly) since the shale oil burns at a lesser value for the coefficient of surplus air and, upon combustion, liberates significantly less flue gas than the shale. Given heat treatment of the shales, there are no nitrogen oxides in the flue gases for practical purposes. Presently field testing of the ash obtainable at the UTT unit and used as a neutralizer for acidic soils are being performed by organizations of the USSR Ministry of Agriculture. The possibility of using it to produce building materials is also being investigated.

Comprehensive industrial testing of the power-producing scheme and development of pilot industrial facilities with an output of no less than 1 million tons of shale per year, as well as testing the operation of large boilers using shale oil should preceed incorporation of the power-producing scheme for using shales on the scale planned.

The power-producing unit of the Estonskaya GRES (Fig. 2) [picture not included] consists of the following divisions: distillation (2 UTT-3000 units), condensation, shale oil purification, scrubbing and thermosettling of the gas turbine fuel; 2 warehouses -- an intermediate one and one for the finished product (the furnace shale oil); general plant structures and a renovated TP-101 boiler.

It is specified that all of the shale oil which is produced will be burned in the renovated boiler furnace, whereas the gas will be burned along with the shale in the furnaces of all of the GRES's boilers. The tar water (about 40,000 tons) will be transferred to enterprises of the petrochemical industry for extraction of the phenols and to be rendered harmless. The possibility of producing 75,000 tons of gas turbine fuel per year is anticipated.

Since the UTT-3000 is at present a custom-made piece of equipment, many questions about the processes for manufacturing the units (e.g. welding, lining the units with abrasive-resistant materials, etc.) were resolved for the first time by installation organizations and producer plants during the process of creating and installing the pilot UTT-3000 units.

These decisions should be used when creating series UTT units for power engineering in the northwestern part of the country in accordance with planned increases in shale mining.

The economic savings and the prospective nature for expanding mining and use of oil shales in the national economy has been confirmed by design studies, technical and economical justification and the conclusions of the USSR Ministry of Power and Electrification and Gosplan's State Committee of Experts.

9194
CSO: 1822

ELECTRIC POWER

UDC 621.165:697.34

HEAT-PRODUCING STEAM TURBINES FOR ATOMIC THERMAL ELECTRIC POWER STATIONS

Moscow TEPLOENERGETIKA in Russian No 5, May 80 pp 2-7

[Article by V. I. Vodichev, Ye. I. Benenson, V. I. Velikovich, A. V. Rabinovich, P. A. Yazov, D. M. Budnyatskiy and L. P. Safonov, Poltava Turbomechanical Plant -- Scientific Production Combine of the Central Scientific Research Institute for Boilers and Turbines]

[Text] The effectiveness of a central heating network based on an atomic thermal electric power station as a highly important direction in heat and power supply has been pointed out in many studies [1-4] and is confirmed by all the experience of the Soviet power industry, whose distinguishing characteristic is the use, on a national scale, of the effect of combined production of electric and thermal energy at thermoelectric stations with heat-producing turboplants. In individual special cases this does not preclude other solutions, such as the use of unregulated output of condensation turbines for the heating of residential areas adjacent to atomic power stations for heating purposes. However, for regions of heat consumption characteristic for the scale of the country the basis for central heating with the use of atomic energy should be atomic thermal electric power stations with heat-producing turboplants.

Here we examine some problems relating to the designing of heat-producing steam turbines for atomic thermal electric power stations.

Requirements are imposed on turbines and turboplants which in part are contradictory; their satisfaction should ensure the successful solution of the problem of creating highly effective atomic thermal electric stations and equipment for them.

1. The type of turbine, its electric and thermal loads, should be optimum from the point of view of the technical-economic feasibility of constructing ATEPS in regions with the most characteristic thermal loads.

2. The design of the turbine and its "flow-through" part, the construction of the network heaters and their positioning, and the scheme for the distribution of steam flows for the output of electric power and the heating

of network water and their control, must ensure the maximum effectiveness of operation in the power system and also the joint functioning of the turbine and the heat networks.

3. The design decisions must ensure the mastery of the equipment in the shortest possible time, which not only will bring closer the time when a direct economic effect is obtained from the ATEPS, but will also favor the speediest possible accumulation of experience for their further improvement. For this purpose, and also for a more effective use of the productive capacities of industry, insofar as possible use should be made of equipment which has been or is being mastered for atomic power stations (reactors, steam generators, electrotechnical and other equipment).

4. A turbine must have characteristics making its use possible under different operating conditions, in particular for different temperature regimes of the ATEPS, since the latter, like other decisions in creating the ATEPS and equipment for it, can be made more precise in the course of the work and be more rigorously standardized on the basis of the results of this work. This condition, naturally, somewhat contradicts the optimization of decisions for any specific conditions of turbine use.

An investigation of the problems involved in the concentration of heat loads over a long period, a study of the technical-economic aspects of construction of ATEPS and equipment for them, the problems of safety and the economically most desirable conditions for heat supply, the problems of standardization of equipment for ATEPS and atomic power stations (AEPS), as well as allowance for the experience in developing large heat-producing turbines for thermal electric power stations operating on organic fuel and other aspects of the problem show that for ATEPS the most effective reactors are those with water under pressure of the VVER-1000 type with an electric power of 1000 MW and heat-producing turbines with a power of 500 MW with a limited heat load (integral condensation power) of the TK type.

The use of turbines of the TK type, new for turbine construction [5], having approximately half the thermal load in comparison with turbines of the T type of this same electric power, makes possible the most successful solution of the problem of creating ATEPS of a high power, which under conditions of a relatively limited thermal load in the adjacent region, with respect to specific capital expenditures and economy of the condensation production of electric power, would be quite close to modern atomic power stations and at the same time would ensure a high effectiveness of the combined production of heat and electric power.

The use of turbines of the TK type at ATEPS does not preclude the development thereafter of turbines of the T type with a power of 500 MW. Such turbines of the T-500 type can be used effectively at ATEPS with VVER-1000 reactors if the thermal load for the ATEPS is approximately 21,000 GJ/hour or more, and jointly with VK-500 reactors in the case of lesser thermal loads (beginning with 10,500-12,500 GJ/hour), if, however, it is demonstrated that it is economically feasible to construct ATEPS with a power of 1,000 MW with VK-500 reactors

The technical design of turbines of the TK-450/500-68(60) type has now been developed and approved applicable to the following conditions:

-- for operation in combination with vertical steam generators having an economizer section and ensuring a pressure of the live steam 6.8 MPa -- a turbine of the type TK-450/500-68;
-- for operation in combination with horizontal steam generators ensuring a pressure of live steam 6 MPa -- a turbine of the type TK-450/500-60.

The turbines are designed to be standardized with one another to the maximum degree possible and differ with respect to the blades of the first three stages and also the presence (in the TK-450/500-60) or absence (in the TK-450/500-68) of a high-pressure heater in the regenerative circuit for the heating of feed water.

The technical specifications for the turbines are given in the table.

Technical specifications	Type of turbine	
	TK-450/500-68	TK-450/500-60
Pressure of live steam, MPa	6.8	6
Temperature of live steam, °C	282.5	274.3
Initial moisture content, %	0.5	
Temperature of intermediate superheating, °C	260	
Separating pressure, MPa	0.97	
Frequency of rotation, rpm	3000	
Expenditure of live steam, tons/hour	3000	3157
Temperature of feed water, °C	198.0	221.2
Electric power, MW:		
in condensation regime	500	
in heating regime	450	
Thermal load, GJ/hour	1880	
Number of heating takeoffs	2	
Range of controlled pressure in upper takeoff, MPa	0.06-0.3	
Range of controlled pressure in lower takeoff, MPa	0.04-0.2	
Expenditure of cooling water, tons/hour	60000	
Computed temperature of cooling water, °C	27	
Pressure in condenser in condensation regime (average for both condensers), MPa	0.00955	
Takeoff for internal needs, tons/hour	60	
Takeoff for turbodrive, tons/hour	60	
Additional takeoffs for external consumption:		
from separating pressure, tons/hour	300	
after third stage, tons/hour	200	

The high effectiveness of the combined production of thermal and electric power in the TK-450/500 turbine is ensured by means of the following solutions, tested in the modern heat-producing turbines of the Poltava Turbomechanical Plant for thermal electric power stations operating on organic fuel: stepped heating of network water, an expanded range of regulated pressure in the heating takeoffs, careful selection of the flow-through part for conditions of maximum annual effectiveness, taking into account the joint operation of the turbine and heating networks, a reduction of underheating in the network heaters and a pressure loss in the takeoff lines. The realization of these solutions involves considerable difficulties in design because the thermal load of the TK-450/500 turbine exceeds by more than 30% the maximum load of the world's largest heat-producing turbine -- the TMZ T-250/300-240 [6].

In order to broaden the possibilities of effective use of the TK-450/500 turbine under conditions of work with different temperature regimes of the heat networks provision was made not only for the two principal heating takeoffs, but two additional takeoffs with a pressure 0.8-1 and 2.2-2.5 MPa.

The turbine (Fig. 1) has four cylinders: high-pressure cylinder (HPC), intermediate-pressure cylinder (IPC) and two low-pressure cylinders (LPC) (LPC1, LPC2). The presence of a separate intermediate-pressure cylinder is attributable to the need for having in the construction of the turbine adjustable heating takeoffs with great mass and volumetric steam discharge.

All four cylinders are two-flow, which ensures compensation of the additional axial stresses characteristic for turbines with steam takeoffs and an increase in the reliability of operation of the blades, especially of the pre-takeoff stages and the stages of the intermediate (between the heating takeoffs) sections of the flow-through part. The number of stages in the HPC is 2 x 6, in the IPC -- 2 x 6, in LPC1 -- 2 x 3 and in LPC2 -- 2 x 4.

The flow-through part of the turbine is constructed with the steam partially bypassing the stages of the intermediate section. A peculiarity of this design [6] is the connection of one LPC to the chamber for conveying steam to the intermediate section, whereas the other LPC is connected to the chamber for delivery of steam after the intermediate section (Fig. 2). The regulating mechanisms for steam entry into LPC1 and LPC2 make it possible to set the required distribution of steam discharge between the two flows. Such a design of the flow-through part makes it possible to increase the mean annual economy of turbines of the TK type operating in a broad range of change in the thermal loads, and at the same time decrease the height of the blades of the intermediate section stages. This favors an increase in the reliability of blading in the intermediate section operating under conditions of a variable regime with considerable changes in the volumetric flow and counterpressure, which is especially important for powerful turbines with great heights of stages in the intermediate section. The adopted design for the flow-through part considerably improves the possibility of a rational layout of the turboplant.

The high-pressure cylinder and its flow-through part operate under conditions similar to the operation of the HPC of purely condensation turbines of saturated steam and are designed in a similar way. The construction of the steam inlet of this cylinder makes it possible to remove the lower half of the inner housing without disassembly of the valves units. The sleeves of the steam inlet are designed with a special configuration, which makes it possible, with an insignificant increase in resistance of the steam inlet, to decrease the diameter of the piston connection, and accordingly, the steam pressures acting on the attachments of the horizontal joint. The takeoff from the HPC to the deaerator after the fifth stage is through sleeves and then through the outer housing. The connection between the sleeve and the outer housing is in the form of a piston connection. In order to avoid "slit" erosion it is provided that the inner housing of the HPC be made from stainless steel.

After the HPC the steam is fed for separation, intermediate superheating and then to the IPC. The latter has a circular construction, consisting of three parts: a cast middle part and two welded end parts, bolted together along the vertical joints. In the upper half of the IPC there are four pipes for the transmission of steam into LPC2 and to the network heater of the second stage (in the cast middle part) and four pipes for the transmission of steam into LPC1 (in the outlet sectors).

In the lower half of the IPC provision is made (in the cast middle part) for two pipes for delivery of steam to the IPC and in the outlet part -- four pipes for the takeoff of steam to the network heater of the first stage.

In LPC1 there are three stages in each flow, unified with the stages of the LPC of a T-250/300-240 turbine, and in LPC2 -- four stages in each flow. The working blades of the second stage, guides and working blades of the third and fourth stages are identical with the blades of the corresponding stages of LPC1. The blades and diaphragms of the regulating stage of LPC2, and also the diaphragms of the last stages of both LPC are being improved.

Both low-pressure cylinders are close in design to the LPC of the T-250/300-240 turbine and have many components unified with them. At the same time, changes have been introduced into the design of LPC1 and LPC2 of the TK-450/500-68(60) turbine. These changes are related to the different sizes and designs of the bushings, with the addition in the LPC2 of a new regulating stage and improvement of the aerodynamic qualities of the outlet pipes. In the turbine there are two "fixation points" which are situated in the outlet pipes of the low-pressure cylinders.

It is provided that all the rotors be made of steel of a new grade quality (27KhN3MFA) with a reduced threshold of cold brittleness.

The system for control of steam flows, corresponding to the most effective use of heat of the steam entering the turbine, that is, to the maximum production of electric power with satisfaction of a particular regime of the thermal network, includes valves HPV which are for control of the electric load, low-pressure valve (LPV) rotatable diaphragms controlling the flow of steam into the principal network heaters of the first and second stages, regulating valves on the lines to the high-pressure network heaters and a rotatable diaphragm for an intermediate-pressure valve (IPV) for controlling the flow into the network heater, fed by steam from the line after the HPC.

The control of the HPV and accordingly the electric load occurs in accordance with the power system regime. Control of the steam distribution mechanisms of the takeoffs is accomplished in accordance with the regimes of the heat network in such a way as to ensure a minimum of losses in regulation of the takeoffs.

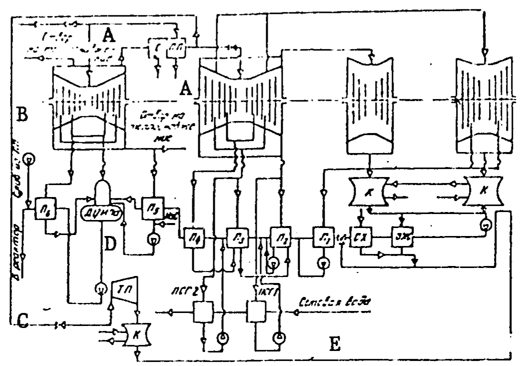

Fig. 2. Structural diagram of thermal system.

KEY:

A. Takeoff to heat supply
B. Overflow from steam line
C. To reactor
D. MPa
E. Network water

In addition to the steam distribution mechanisms, accomplishing control of the normal turbine regimes, provision is made for protective mechanisms: shutoff valves HPV and rotatable shutoff gates IPV. The latter are necessary due to the great energy accumulated in the steam, droplets and condensate film in the turbine HPV and steam distribution line.

The HPV regulating and shutoff valves are situated in two blocks which are welded to the lower half of the HPC. The two welded rotatable diaphragms of the IPV and the two paired diaphragms of LPV1 and LPV2 are situated in the steam inlet chambers. The four IPV shutoff gates are placed in the steam lines from the steam distribution system to the IPC. There are servomotors for driving the steam distribution mechanisms regulating the normal regimes. These servomotors are controlled by the system for turbine regulation; for the drive of the shutoff valves and gates there are automatic shutoff mechanisms which receive signals from the protection system.

The turbine regulation system is electrohydraulic; it contains circuits for regulating the frequency of rotation and power and also a circuit for regulating the takeoffs. The circuit for regulating the frequency of rotation is entirely hydraulic; it ensures high-speed regulation of the frequency of rotation, including jointly with electrohydraulic conversion -- a restraint of load dropoff.

The power regulators and takeoffs are electronic, proportionally integral; they make it possible to increase the accuracy in maintaining the set parameters and thereby the level of automation and the economy of operation of the turbine by choice of the most economical control method and a decrease in the deviations from the stipulated regime without intervention of servicing personnel. The temperature of network water was selected as the regulated takeoff parameter. Provision is made for the possibility of control of the turbine operating regime on the basis of the temperature of the direct network water or on the basis of the difference between the temperatures of the directly flowing and returning water, directly characterizing the thermal load.

The electric part of the regulation system is constructed using equipment in standard production by industry and widely used at thermal electric power stations. The design solutions for the hydraulic part of the regulation system are based on construction components which have been reliably tested and which have recommended themselves well in operation.

OMTI fuel oil will be used as the working fluid in systems for regulating and lubricating the turbine. This is a new decision for heat-producing turbines, whose regulation systems are more complex than in condensation turbines and have large oil consumption. It requires the carrying out of experimental studies and experimental final adjustment of regulation system units applicable to the conditions for work with OMTI.

The thermal systems of moist steam turbines of atomic electric power stations are characterized by the presence of external separation and intermediate superheating of the steam. The choice of the principal parameters of separation and intermediate superheating (structural diagram, separation pressure, temperature of intermediate superheating, characteristics of apparatus, etc.) exerts a considerable influence on the economy, reliability and cost of the turboplant. Detailed investigations carried out for condensation atomic turbines cannot be used directly for heat-producing turbines because in these turbines the pressure of the spent steam is considerably greater.

In the development of the design for the TK-450/500 turbine on the basis of an earlier made general investigation [8] it was possible to determine the optimum parameters of separation and intermediate superheating and change in the economy of the turbine with deviation from the optimum solutions and also the possibility of unification of the entire thermal system with condensation turboapparatus of units with VVER-1000 reactors.

It should be noted that for unification with condensation units and also increasing the reliability the TK-450/500 turbine has single-stage intermediate superheating of steam, despite the lesser (0.2% as an average for a year period) computed economy in comparison with the two-stage intermediate superheating of steam.

The system for regenerative heating of the feed water is unified with the condensation units and provides for the successive heating of the feed water in the main ejectors, ejectors for suction from the sealings, four low-pressure heaters (LPH) of the mixing type, four LPH of the surface type and a 1.2 MPa deaerator with subsequent heating by means of mixing of the feed water with the condensate overflow of the heating steam of the steam distribution system. The thermal system of the TK-450/500-60 turbine is supplemented by one HPH.

The heating of network water is accomplished successively in the main network heaters by steam from two heating takeoffs. The condensate of the heating steam is pumped into the feed line after LPH2 and LPH3 respectively. With a deterioration of condensate quality provision is made for the emergency discharge of condensate from the network heaters and turbine condensers.

In the network heaters it is possible to heat network water to 126°C, which corresponds to a heating factor of 0.6 in the case of a temperature regime of the thermal networks 170-60°C. In order to heat network water above 126°C, as is required, for example, when the peak boiler unit is placed outside the ATEPS or in the case of a single-pipe heat supply system, it is possible to use two additional steam takeoffs:

-- a takeoff after the HPC in a quantity up to 300 tons/hour with a pressure 0.8-1 MPa, due to which it is possible to heat the network water in an additional network heater to 160-170°C;

-- a takeoff after the third stage in a quantity up to 200 tons/hour with a pressure 22-25 MPa.

As a result of use of both takeoffs it is possible to ensure heating of network water in additional network high-pressure heaters to 205-210°C. This solution, naturally, complicates the design of the turboplant, but broadens its operational capabilities.

The thermal system provides for the installation of a feed pump for 100% output with a condensation turbodrive. The steam is fed to the turbodrive from the separation pressure line after the steam distribution line.

The principal parameters of the low-potential part of the turboplant (number of flows at the output, surface of condenser, volume of cooling water, computed vacuum, etc.) were selected on the basis of optimization computations made at the turbomechanical plant in collaboration with the Scientific-Production Combine of the Central Scientific Research Institute for Boilers and Turbines.

Investigations indicated that for the considered conditions of circulatory water supply and with a length of the working blade of the last stage 940 mm (circular area 7.1 m^2) the optimum solution is a TK-450/500 turbine with four flows, that is, with two LPC.

The condenser group of the turboplant consists of two condensers with a heat exchange surface of 19,000 m^2 each. On the water side the condensers are single-pass, two-flow; they have separate bundles of pipes for the heating of makeup water to the temperature of heating of the circulation water and an apparatus for the reception of steam after regulation in a quantity of 60% of the nominal flow of live steam to the turbine when there is a load dropoff.

With respect to cooling water the condensers are connected in series, which makes it possible to increase economy in the condensation regime with a nominal temperature of the cooling water at the inlet equal to 27°C by 0.15% in comparison with the parallel passage of water. The investigations indicated that the greatest effect from stage condensation when functioning in heat-producing regimes is obtained with the passage of cooling water first through a condenser with a lesser and then through a condenser with a greater thermal load. The adopted system for circulatory water supply ensures an optimum regularity in the successive passage of cooling water.

Computational investigations of turbine maneuverability were made; the results make it possible to determine the maneuverability of the TK-450/500 turbine at the level of maneuverability of purely condensation moist steam atomic electric power stations.

The computations indicate that the use of ATEPS with TK-450/500 turbines, in comparison with separate production of thermal (at atomic heat supply stations) and electric (at AEPS) power, will give a savings of 40 million rubles for one power unit of 1000 MW with two TK-450/500 turbines.

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ELECTRIC POWER

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HEAT ENGINEERING EQUIPMENT FOR GEOTHERMAL ELECTRIC POWER STATIONS

Moscow TEPLOENERGETIKA in Russian No 5, May 80 pp 29-33

[Article by Yu. A. Averbakh, V. A. Bonesko, A. A. Itskovskiy (Engineers) and Yu. P. Kosinov, O. S. Naymanov (Candidates of Technical Sciences), Khar'kov Affiliate, Central Design Bureau Glavenergoremont]

[Text] The thermal system of a geothermal electric power station (GEPS), making use of the earth's heat, is illustrated in Fig. 1. A steam-water mixture from a borehole 1 is fed into a separator 2 from which the separated steam is directed into a steam turbine 3, whereas the separating water is fed through the accumulating tank 4 into the expansion unit 5. The steam-water mixture from the expansion unit is directed to a special steam-vacuum turbine 6 or to the main turbine. The condensation unit consists of the condensate itself 7 and an air-exhaust unit 8. The steam excess arriving from the separators is discharged into the atmosphere through the muffler 9 when there is a decrease in the load on the GEPS.

We will briefly examine the principal characteristics of the design and operation of the above-mentioned equipment.

Steam-Water Boreholes

The economy of operation of a GEPS is related to a considerable degree to the borehole operating conditions. With a constant initial enthalpy of the ground water i_0, stratum pressure and filtration properties of the rocks the yield of an individual borehole and its dependence on pressure at the mouth are determined by the conditions of movement of the steam-water flow along the borehole shaft.

In turn the dependence of the yield D_{sw} on pressure at the mouth p_{mouth}, called the borehole characteristic, determines the optimum initial steam pressure before the turbine.

Mutual allowance for the degree of decrease in flow of the steam-water mixture with an increase in pressure at the mouth and turbine power with an increase in the initial pressure determine the maximum of the function

$$N = f_1(p_0, p_{\text{K}}, G), \quad (1)$$

[K = fin(al)]

where N is the power of the GEPS turbines; p_{fin} is the final pressure; p_0 is the pressure before the turbine, equal to the pressure at the mouth, less the loss in the steam pipe; G is the steam flow through the turbine, determined from the thermal computations for the separator;

$$G = \frac{D_{\text{п.в}}(i_0 \eta_c - i_{p_y})}{r_{p_y}}; \quad (2)$$

[c = sep(arator); y = mouth; П. В. = sw = steam-water] η_{sep} is separator efficiency; $i_{p_{mouth}}$ is the enthalpy of the saturated steam with a pressure in the separator approximately equal to the pressure of the steam-water mixture at the mouth; $r_{p_{mouth}}$ is the latent heat of vaporization corresponding to p_{mouth}.

An example of the dependence $D_{sw} = f(p_{mouth})$ is illustrated in Fig. 2,a.

Computations using the presently known characteristics of boreholes, with expressions (1) and (2) taken into account, give a level of optimum initial steam pressure for the GEPS turbines averaging 0.1-0.5 MPa. The p_0 value is determined in greater detail by the specific parameters of the hydrodynamics of steam-water boreholes. If the borehole diameter is small, its yield is artificially restricted; however, if at the outlet the diameter is too great, under definite conditions with a decrease in p_{mouth} the borehole can enter a pulsating regime of variable yield.

The difficulty in selecting the optimum geometry of boreholes is related to a substantial inequality of the velocities of the steam and liquid phases, which in the computations makes it necessary to use a semiempirical method for determining the true volumetric vapor content φ. This problem was examined in greater detail in a study by O. S. Naymanov [1]. Employing the data from tests of steam-water boreholes in the Pauzhetskiy thermal region it was possible to establish empirically the two principal coefficients by means of which the two-phase flow can be computed using the formulas of homogeneous flow; c is a correction factor for determining φ from the discharge volumetric vapor content β using the formula $\varphi = c\beta$; the β value is easily computed using the stipulated steam dryness [2]; ψ is a correction factor for scaling the losses in friction during the movement of a two-phase flow in the region $\beta \geqslant 0.7$, accomplished using known formulas on the assumption that the flow is homogeneous [2].

The results are presented in Fig. 2,b,c. The computations made on the basis of the coefficients cited above made it possible to draw a number of conclusions concerning the construction of boreholes and to evaluate the optimum initial steam pressure before the turbines at the Pauzhetskaya GEPS at 0.12-0.15 MPa.

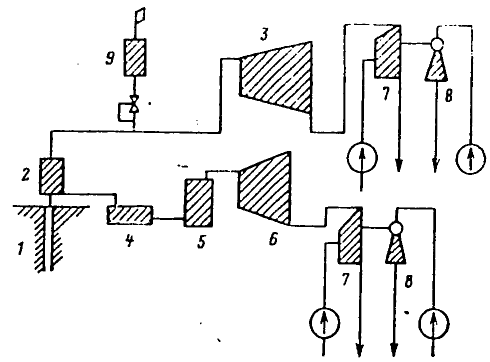


Fig. 1. Thermal system of geothermal electric power station.

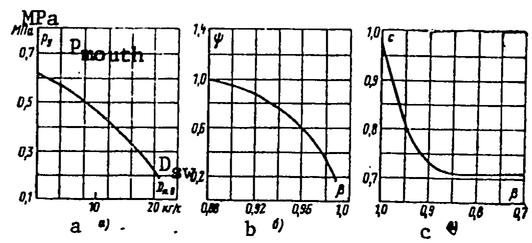
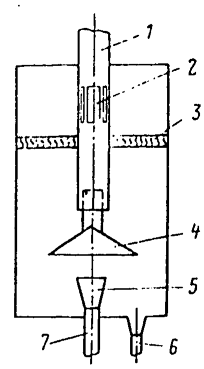


Fig. 2. Characteristics of movement of two-phase flow in steam-water boreholes. a) example of dependence of yield of borehole on pressure at mouth; b) dependence of correction factor ψ for scaling losses in friction during movement of two-phase flow on discharge volumetric vapor content β ; c) dependence of correction factor c on β for determining true volumetric vapor content φ . The curve was constructed on the basis of experimental values for a heat content t_0 = 750 KJ/kg (p_0 = 1.0 MPa).

Fig. 3. Jalousie separator. 1) steam outlet; 2) windows; 3) jalousie trap; 4) moving recoil cone; 5) diffuser; 6) water overflow; 7) entry of thermal mixture



Separators for Steam-Water Boreholes

High-volume standard-produced centrifugal separators were earlier installed in the boreholes on Kamchatka. These are intended for the separation of a steam-water mixture with a pressure of 0.4-1.5 MPa or more. Separators of a similar design are being used in geothermal boreholes abroad where the pressure of the steam-water mixture considerably exceeds the pressure in the operational boreholes of the Pauzhetskaya GEPS. These separators are unwieldy, complex in design and have a relatively high hydraulic resistance. They cannot be installed directly at the borehole, which leads to losses in the separator itself and there is increased loss during the transport of the steam-water mixture from the borehole to the separator. The separator developed for installation at the Pauzhetskaya GEPS is free of these shortcomings (Fig. 3).

The geothermal mixture is fed through a diffuser to a recoil cone where large water droplets are separated from the steam. Bathing the recoil cone, the steam passes through jalousies in which small water droplets are separated from it. The separated steam, after final separation, is fed into an outlet pipe.

The recoil cone can be moved in a vertical direction for creating an optimum separation regime for different borehole yields.

The operation of the separator at the Pauzhetskaya GEPS demonstrated the operability of the design and its advantages over earlier used designs were confirmed.

Turbines

Turbines of the following types can be used at GEPS: steam, operating on steam from a separator; steam-vacuum, as the working medium using water vapor at a pressure less than atmospheric, generated in expansion units from superheated water; hydrodynamic, using the kinetic energy of a steam-water stream emanating from a borehole; turbines in which the working medium is substances with low boiling points (for example, freon, butane, etc.). There is now long experience in operation of only steam turbines.

The results of the corresponding design developments of hydrodynamic and steam-vacuum turbine plants at the Khar'kov Affiliate of the Central Design Bureau and the first experience in their operation at the Pauzhetskaya GEPS make it possible to predict quite reliably the possibilities of their future use.

Hydrodynamic turbines are the simplest in design, not requiring any additional units other than generators. An experimental model of such a turbine was designed on the basis of theory and the adopted norms for "scoop" hydroturbines and fabricated at the Poltava Turbomechanical Plant (PTMP). Tests of this turbine indicated that the maximum efficiency, calculated relative to the disposable kinetic energy of the steam-water mixture emanating from the borehole, falls in the range 30-40% [3].

With a further improvement in the design of hydrodynamic turbines their efficiency can be increased, but even for the attained efficiency in boreholes with a high head it is possible to obtain a power of 100 KW or more, thereby substantially lessening the cost of exploitation of new thermal regions. [The first design of such a turbine was proposed by V. V. Aver'yev and V. G. Renne.] The computations show that for these same purposes it is also possible to use ordinary steam one- and two-stage turbines operating on the exhaust principle. In this case the necessary conditions should be a sufficiently high initial enthalpy of the thermal water (not less than 627-711 KJ/kg) and a quite high borehole yield with $p_{mouth} \approx 0.2$ MPa (not less than 15 kg/sec).

The use of steam-vacuum turbines is of special interest for GEPS. The installation of such turbines makes possible a 20-30% (depending on the t_0 value) increase in the power of the electric power station without a change in the number of boreholes. This is achieved by the use of separated water with an enthalpy of 419 KJ/kg or more or thermal water with i_0 = 335-419 KJ/kg. For such turbines it is necessary to organize an additional delivery of steam in a case when use is made of several successive expansion stages in expansion units connected in series.

In the first stages of GEPS it is best to use one or a maximum of two steam expansion stages. Figure 4 shows that beginning with two expansion stages each new stage, that is, an additional expansion unit and the input of steam into the turbine, already insignificantly increases the power of the GEPS and therefore is not justified. Another peculiarity of steam-vacuum turbines is a special regulation and steam distribution system. With a change in the operating regime of these turbines the steam distribution organs must not only ensure a change in the volume flow of steam through the turbine, but also a corresponding decrease in the steam-water mixture from the expansion unit. The problem is complex, for example, because with a decrease in the load the pressure before the turbine decreases proportionally to the change in steam volumetric flow; on the other hand, in the expansion unit there is an increase in the steam-water mixture with a decrease in pressure.

The first experimental steam-vacuum turbine in the USSR, with a power of 400 KW, designed at the Khar'kov Affiliate of the Central Design Bureau and fabricated at the Poltava Turbomechanical Plant, was installed at the Pauzhetskaya GEPS. The performance of the turbine proper, including regulation, was confirmed but a substantial deviation of the test parameters from the nominal design parameters does not make it possible to give a reliable comparison of the computed and experimental characteristics. This problem will be solved after modifying the design and operation of a special condenser in this apparatus. In evaluating the future prospects for use of steam-vacuum turbines it must be noted that no fundamental problems related to the designing and fabrication of these high-power (20-30 MW)

Паровые конденсационные турбины 1				Геотермальные турбины 2							
				паровые 3				паровакуумные 4			
мощность, МВт 5	завод-изготовитель 6	объемный пропуск пара через ЦНД, м³/с 7	давление пара перед ЦНД, МПа 8	мощность, МВт 5	начальное давление пара, МПа 9	объемный пропуск пара через турбину, м³/с 7	число оставленных в работе ступеней 10	мощность, МВт 5	начальное давление пара, МПа 9	объемный пропуск пара через турбину, м³/с 7	число оставленных в работе ступеней 10
100	ЛМЗ 11	2500	0,19	25	0,10 (0,13)	2300	2×4	25	0,05 (0,07)	2600	2×3
100	ХТГЗ 12	2800	0,14	30	0,10 (0,14)	2800	2×4	30	0,05 (0,07)	2900	2×3
150	ХТГЗ	3200	0,45	75	0,45 (0,45)	3400	2×6	—	—	—	—
300	ХТГЗ	3900	0,24	50	0,13 (0,13)	4300	2×4	50	0,06 (0,06)	4000	2×3
500	ХТГЗ	7400	0,30	100	0,17 (0,17)	6500	×4	—	—	—	—

Note: All the figures are rounded off.

KEY:

1. Steam condensation turbines
2. Geothermal turbines
3. Steam
4. Steam-vacuum
5. Power, MW
6. Manufacturing plant
7. Volumetric passage of steam through LPC, m^3/sec
8. Steam pressure before LPC, MPa
9. Initial steam pressure, MPa
10. Number of stages remaining in operation
11. Leningrad Mechanical Plant
12. Khar'kov Turbogenerator Plant

turbines should be expected. Figure 4 illustrates the specific power of the turbine obtained from 1 ton of thermal water per hour in dependence on different initial parameters. The curves show that the optimum temperature at which the generation of steam should occur in the expansion unit (with up to two expansion units) falls in the range 70°C. However, taking into account the total quantity of metal used in a turbine and steam lines, it is desirable to set this value somewhat higher (approximately 80°C), which corresponds to a pressure before the turbine of approximately 0.5 MPa. With such an initial pressure for a steam-vacuum turbine with a power of 25 MW or less the volumetric flow of steam through the last stage is in a range up to 4,000 m^3/sec. The table gives the approximate values of the nominal volumetric steam flows through the last stages of some presently operating turbines (scaled to one low-pressure cylinder (LPC)), and also the computed values for the volumetric flow of steam through steam-vacuum turbines of different power. We can see that for turbines with different capacity it is entirely possible to use LPC of existing turbines. The noncoincidence with respect to initial pressure is compensated by removing some of the stages of the LPC of the corresponding turbines. The table gives the nominal pressures before the LPC; the pressure before the stages remaining in operation is indicated in parentheses. These pressures are quite close to the necessary pressure before the steam-vacuum turbine. Some of the turbines of those mentioned in the table in the next few years are planned for dismantling due to reduced economy or due to metal fatigue of the boilers and many of the cast parts of the LPC. At the same time the rotors, blades and LPC, as indicated by an analysis of their actual condition, can be used reliably for a long time, especially at geothermal electric power stations.

The comments made concerning powerful steam-vacuum turbines are also correct for steam turbines, which at the present time and in the coming years will be the principal type of turbines at a GEPS.

Still more suitable for steam turbines are the LPC of high-pressure turbines, both with respect to the level of initial pressure and with respect to the steam delivery conditions, since in this case no additional steam delivery is required. The table gives the basic data characterizing the possibility of use of LPC of existing turbines for GEPS. We see that the closeness of the initial parameters of future GEPS and presently operating LPC is quite high.

Under the real conditions of GEPS construction there can be different values of the optimum initial pressure and steam flow through the turbine. However, when using the LPC of existing turbines, the variety of which is very great, with any initial data, as indicated by computations, it is possible to select the LPC of disassembled or already fabricated turbines. Some possible modernization of the first stages can be accomplished without difficulty.

Now we will briefly consider the values of a unit power of steam turbines at GEPS. It is known from foreign and Soviet experience in the exploitation of geothermal regions that the total resources of the working medium the limits of a definite area is limited. Augmentation of the total yield by the exploitation of more remote sectors for one GEPS becomes unjustifiable as a result of the increase in cost of the lines and heat losses in them. Specifically, the limited radius of the thermal region used for one electric station is dependent on many initial parameters and according to rough computations must fall in the range 2-3 km. With a greater area of the thermal region it is necessary to construct new electric power stations.

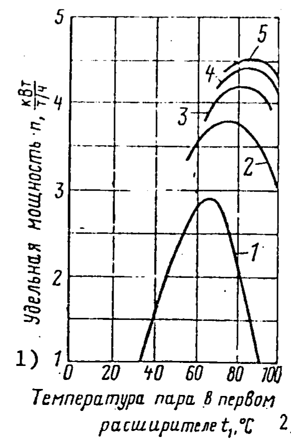


Fig. 4. Specific power of steam-vacuum turbine in dependence on number of expansion units.

KEY:
1. Specific power n, KW/tons/hour
2. Steam temperature in first expansion unit t_1, °C

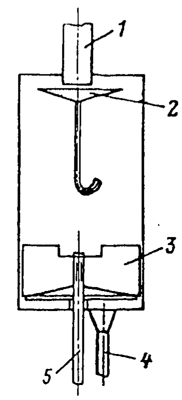


Fig. 5. Slit expansion unit. 1) steam outlet; 2) trap; 3) blades; 4) water overflow; 5) intake of thermal water

Taking this circumstance into account, it can be postulated that the maximum power of a single turbine will fall in the range 30-50 MW. This is also indicated by the following peculiarity of construction of GETS. As is well known, the construction of a geothermal electric power station is accomplished in the following sequence: exploratory drilling of the region proposed for use; protection of the determined reserves of steam-water mixture; drawing up of technical documentation for the GETS on the basis of the confirmed reserves and with the corresponding technical-economic prerequisites, construction of the electric power station. Under these conditions the awaiting of a full study of the thermal region and the delivery of all available reserves of steam-water mixture to the surface prior to the planning of the GEPS will result in a considerable delay in entry of the electric power station into operation and will not be justified economically. The progressive exploitation of the thermal region and stage-by-stage construction of electric power stations is more tenable. GETS in the USSR and abroad are being constructed in this way. This also decreases the proposed unit power of GETS turbines. What has been said above is also confirmed by the experience of foreign GETS. For example, in 1977 the unit power of operating turbines in the GETS of New Zealand was in the range 10-30 MW, Italy -- 5-30 MW, Iceland -- 10 MW, Japan -- 10-50 MW, United States -- 15-55 MW (only one turbine has a power of 106 MW). Most of the turbines planned for construction in the next few years will also have a power up to 55 MW inclusive. It should be noted that the initial parameters of the exploited working medium at foreign GETS are higher than in the USSR and accordingly the optimum unit power of turbines should be greater.

Thus, it can be proposed with assurance that the economically feasible unit power of GETS turbines in the USSR in the immediate future (for not less than 10-15 years) will be in the range 25-30 MW. The table shows that for these turbines it is entirely possible to use the LPC of 100-MW turbines, whose planned disassembly has already begun. It therefore follows that geothermal electric power stations will make it possible to economize not only fuel, but also the expenditures of labor in the planning and fabrication of the main equipment, increasing the useful life of the turbines.

For high-power turbines it is possible to use the LPC of turbines with a power of 300-500 MW, at the present time constructed by Soviet pipe-making plants.

The use of working media with low boiling points for employing the earth's heat with a low potential (70-90°C) can be economically justified for individual sources [4], although one should not expect extensive deployment of power plants of this type because of a number of specific circumstances.

Expansion Units

As has already been noted, one of the components of a steam-vacuum turbine plant is expansion units. The operation of an expansion unit is based on the principle of instantaneous boiling of the entering thermal water with a temperature exceeding by 10-20°C the temperature of saturation corresponding to the pressure in the apparatus. Expansion units of two types have been installed at the Pauzhetskaya GEPS -- an axial expansion unit of the slit type designed at the Khar'kov Affiliate of the Central Design Bureau and a centrifugal expansion unit with a design similar to cyclone separators. The expansion units of both types ensure a steam moisture content at the output of not more than 0.5%.

The water enters an expansion unit of the slit type (Fig. 5) through slits in the delivery pipe; the "superheated" water instantaneously boils and is directed downward, first passing through channels formed by the blades. The forming steam-water mixture is directed upward and is separated as it rises, then passing through additional separation in the upper part of the expansion unit -- in the separation trap. The separated steam is fed into the turbine, whereas the thermal water remaining in the expansion unit pours through an annular slit into the lower cavity, then into the next expansion unit and from the latter into the sewer system or for use in heat supply.

The separation of steam occurs as the steam-water mixture rises. The velocity of the steam is selected from the condition of inadmissibility of entry of water droplets into the exhaust pipe. Specialists in the Scientific-Production Combine of the Scientific Research Institute for Boilers and Turbines have experimentally derived a computational dependence for determining the maximum admissible velocity of steam through a section of the expansion unit.

In an expansion unit of the centrifugal type the heated water is tangentially introduced into a vertical cylinder in whose middle part is a steam pipe. With entry of water into the cylinder there is boiling and preliminary separation as a result of casting of the heavier particles of moisture toward the periphery.

Condensation Apparatus

The small supplies of cooling water, the aggressiveness of the thermal water and the absence of any need for utilizing the spent steam determined the choice of design of a barometric condenser of the mixing type.

The condensers installed at the Pauzhetskaya GEPS are equally suitable for steam and water.

In mixing condensers the drawing-off of the steam-gas mixture (uncondensing gases) is accomplished by a special water-jet ejector installed at the same level as the condenser.

The use of ejector-mixing condensers makes it possible to dispense with a water-jet ejector. Condensers of the mentioned types and water-jet ejectors have been described earlier [5]. However, nozzles with deflectors have been used for the first time for the spraying of cooling water in the condensers of the mixing type at the Pauzhetskaya GEPS.

The material of the condensers and ejectors and anticorrosion layers were adopted in accordance with the recommendations of the Heat Engineering Institute.

An ejector-mixing condenser was installed with an experimental turbine of 400 KW at the Pauzhetskaya GEPS. Preliminary tests revealed an inadequate capacity of the system for the discharge of cooling water.

In general it can be noted that the first years of operation of the auxiliary equipment at the Pauzhetskaya GEPS indicated its operability, but for the optimum perfection of the design of this apparatus and increasing the economy of its operation there must be representative thermal tests of operation of the turboplant in different operating regimes.

Conclusions

1. The designing and fabrication of heat engineering equipment for geothermal electric power stations (including equipment for powerful GEPS) do not meet with fundamental difficulties if based on the use of steam turbine plants.

2. As the steam turbines for GEPS in the next few years it is recommended that use be made of the LPC of standard-produced (including disassembled) turbines, modernized in case of necessity for optimum operation on subsurface heat with definite parameters.

3. A major role in determining the optimum characteristics of GEPS should be played by special thermal tests of steam boreholes, turbines and auxiliary equipment, which up to the present time have been carried out in an inadequate volume.

4. The cited parameters c and ψ of a two-phase flow make it possible to carry out refined computations of boreholes, separators and pipes taking into account the different actual velocities of the phases.

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